EVALUATION OF BITE FORCE AND MASTICATORY PERFORMANCE IN PATIENTS REHABILITATED WITH TOOTH-SUPPORTED OVERDENTURES

A Dissertation Submitted to the
Tamil Nadu Dr. M.G.R. Medical University

In partial fulfillment of the requirement for the degree of

MASTER OF DENTAL SURGERY

(BRANCH I)
(PROSTHODONTICS AND CROWN & BRIDGE)

APRIL 2011

CERTIFICATE

This is to certify that the dissertation titled **"Evaluation of Bite force and Masticatory performance in patients rehabilitated with tooth-supported Overdentures"** is a bonafide record of work done by **Dr.S.Egammai** under my guidance, during her postgraduate period of 2008-2011. This dissertation is submitted to The TamilNadu Dr. MGR Medical University, Chennai, in partial fulfillment for the degree of **Master of Dental Surgery** in Branch I – Prosthodontics and Crown & Bridge. It has not been submitted partially or fully for the award of any other degree or diploma.

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DECLARATION

I, Dr.S.Egammai, do here by declare that the dissertation titled "**Evaluation of Bite force and Masticatory performance in patients rehabilitated with tooth-supported overdentures**" was done in the Department of Prosthodontics, Tamil Nadu Government Dental College & Hospital, Chennai -600 003. I have utilized the facilities provided in the Government Dental College for this study in partial fulfillment of the requirement for the degree of **Master of Dental Surgery** in the specialty of **Prosthodontics and Crown & Bridge (Branch I)** during the course period 2008-2011 under the conceptualization and guidance of my dissertation guide, **Dr.C.Thulasingam, MDS.**

I declare that, no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission from the Tamil Nadu Government Dental College & Hospital.

I also declare, that no part of this work will be published either in the print or electronic media except with those who have been actively involved in this dissertation work, and I firmly affirm, that the right to preserve or publish this work rests solely with the prior permission of the Principal, Tamil Nadu Government Dental College & Hospital, Chennai 600 003, but with the vested right that I shall be cited as the author(s).

Signature of the PG Student   Signature of the HOD

Signature of the Head of the Institution

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CONTENTS

INTRODUCTION

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Edentulism leads to an acknowledged impairment of oral function with both aesthetic and psychological changes. It was evident that tooth loss started a cascade of alveolar bone loss, irrespective of the health of the overall skeleton. Also, adaptation to conventional complete dentures is a complex learning process, when considered on a somatic and psychological basis. Due to the ongoing residual ridge resorption, physiological intra-oral changes and the development of altered muscular patterns, patients remained dissatisfied and had retention and stability problems of the mandibular dentures, in particular. Also, masticatory function in subjects with conventional dentures is reduced to a great extent when compared with healthy dentate subjects, depending on age and dietary habits. Therefore, denture wearers need more masticatory cycles to reduce the food bolus to half of its original size.

One of the therapeutic approaches which has the twin objectives of prolonging the useful life of a residual dentition and enhancing a patient's prosthesis wearing experience frequently are met by the overdenture. The presumed benefits include enhanced denture stability and chewing performance, plus preservation of residual ridge integrity and versatility of application.

It is therefore acknowledged that patients with overdentures gaining support, stability and retention either from teeth, roots of teeth and implants have more predictable prosthodontic outcomes than conventional complete denture wearers.

THE OVERDENTURE CONCEPT –

An overdenture is a complete denture or removable partial denture that has one or more tooth roots or implants to provide support. Overdenture therapy envisages essentially a preventive prosthodontic concept since it attempts to conserve the few remaining natural teeth. The physiologic tenets being continued preservation of alveolar bone around the retained teeth and the presence of periodontal feedback mechanisms that guide and monitor the gnathodynamic functions.

The key factor to this procedure is the effective endodontics. This allowed for a shortened dental crown, which created adequate space for the overlying artificial denture tooth and denture base. Moreover the shortened crown also changes the crown to root ratio thus the reduced mobility of the root improves the bone support. More bone loss occurs in the anterior areas than the posterior areas of the jaws, and in the mandible when compared with the maxilla. Thus the area that is most critical for maintaining teeth to retain alveolar bone is the anterior region of the mandible.

The root overdenture philosophy postulated a transfer of occlusal forces to the alveolar bone through the periodontal ligament of the retained roots. Proprioceptive feedback from the periodontal ligament was conceived to act to prevent occlusal overload and consequently avoid residual ridge resorption adjacent to the roots and the rest of the residual ridge because of excessive forces. They also provided improved function compared to conventional complete dentures such as improved biting force and chewing efficiency, and even phonetics. The impairment of these functional parameters caused by edentulism reveals the significant role of periodontal receptors for sensory feedback and discriminatory ability from retained roots. Complete tooth loss results in loss of discrete proprioception that has been part of the sensory programme throughout life.

Retention is a key element in the removable prosthodontics, for a patient's satisfaction. **Burns et al**.[1] found a strong patient preference for the overdenture attachment with superior retention. Though many factors such as proper border extensions, adhesion, neuromuscular control etc. contribute to the retention of mandibular overdenture, still overdenture attachments play a chief role. Bars, studs and magnets are widely used. **Van Kampen and colleagues**[2] compared patients' satisfaction with implant overdentures retained by ball attachments and with those retained by bars, and found no difference.

The goal of dental restoration is to improve the masticatory function of patients who have lost teeth. Simple, reliable methods for measuring masticatory function would be useful aids in evaluating the success of dental restorative procedures. There have been several objective measures of masticatory functions, such as masticatory performance, swallowing threshold and occlusal force, which require specific instruments, materials, or complicated procedures. Gunne et al.[38] reported that an improvement in masticatory performance does not imply the same improvement in chewing experience and vice versa, measurement of masticatory performance and maximal occlusal force may provide essential information that could make an appropriate diagnosis regarding masticatory function. The most common technique for qualifying chewed food has been to measure particle size distribution with a series of mesh sieves since 1950, using both real foods and artificial materials. The search for new methods and test food to simplify the

procedure, reduce the time involved in testing and provide more relevant measures of assessing the masticatory function is still unresolved.

So, considering the aspects mentioned above, the present study was performed to assess the functionality of the tooth-supported overdentures using simple and reliable objective tests, to measure the bite force and masticatory performance.

AIM AND OBJECTIVES

AIM :

To evaluate the bite force and masticatory ability of different overdenture attachments and conventional complete dentures with reference to natural dentition by using a strain gauge transducer and artificial test food.

OBJECTIVES :

1. To assess the bite force exerted by complete denture patients and patients wearing root-supported overdentures.
2. To analyze the bite force of both the groups of patients with that of dentate individuals
3. To evaluate the bite force of both complete denture and over denture patients by using an indigenously designed strain gauge transducer.
4. To evaluate the masticatory ability of both complete denture and overdenture patients by using a two-coloured wax test food.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This literature review is presented in three parts,

1. Rationale for the Overdenture treatment
2. Attachments and Copings used to retain the overdentures
3. Masticatory ability and bite force, its assessment and implications

RATIONALE FOR THE OVERDENTURE TREATMENT

Preserving natural teeth to support complete dentures is a step in the direction of Preventive Prosthodontics. Preservation of the residual ridge, support and stabilization for the denture base, and giving patients a sense of security in knowing that teeth aid in support of their prosthesis are but a few of the benefits derived from the overdentures.

Hayes (1861)[3] reported the results of fabricating a complete denture over two roots in the maxillary arches and 12 years later, they were still in place contributing to the comfort of the patient. ***Black (1945)***[4] provided complete denture for a 14-year old girl with a congenital absence of the permanent teeth with retention of four maxillary and mandibular teeth. In 1972, 27 years later, the mandibular deciduous molars were still intact supporting the complete mandibular overdenture.

Majority of natural teeth used to support overdentures are devitalized and treated endodontically, but they still had sensory input capabilities equal to that of the vital teeth[5].

Paul A. Miller (1958)[6] reported that retention of a few teeth under complete dentures allowed the weak teeth to regain healthy status, aiming at reduction of load on the osseous portions of the denture bearing area, thereby minimizing the process of resorption. This foresight was of prime importance in convincing the profession that the overdenture was a superior treatment modality.

Kawamura and Watanabe (1960) [7] found that patients with natural dentition could discriminate differences at the 2 mm range better than those with artificial dentures. These findings emphasized the importance of conservative procedures and the importance of the retention of natural teeth. Most of the times, mandibular canines are retained for lending support to the retention for the overdenture, because of its dense innervation than any other teeth[8].

Kawamura and Grossman (1964)[9] agreed that the sensitivity in the anterior part of the mouth, particularly the periodontal ligament of the anterior teeth, tongue tip, and mucosa, was acute because of its greater concentration of sensory receptors. Also, these signals from the periodontal and mucosal receptors are important in controlling and determining the biting force.

Johnston and associates (1965) [8] stated that “a bridge is indicated whenever there are properly distributed and healthy teeth to serve as abutments, provided these have suitable crown-root ratio and that after radiographic, diagnostic cast and oral examinations seem capable of sustaining the additional load. When, a few retainable teeth are scattered generally throughout the arch, and invariably they are involved periodontally with unfavorable crown-root ratios, the overdenture option should be considered.

Morrow et al (1969)[10] gave the indications and contraindications for planning tooth-supported overdentures and described the technical aspects of overdenture fabrication. They also discussed the various clinical situations, their advantages and disadvantages.

James L. Lord & Stephen Teel (1969)[11] stressed that teeth that are too weak for normal partial dentures may be suitable for over denture abutments. This type of approach was particularly recommended when denture was opposed by natural teeth but contraindicated when the remaining teeth are adequate to restore the dental arch with fixed or removable partial denture. Teeth should be retained where the occlusal forces on residual ridge are greater.

Tallgren(1972)[12] found that reduction of mandibular residual ridge height was 6 times greater than the maxillary residual ridge. Mean loss of mandibular ridge was 9 to 10 mm over a 25-year denture-wearing period whereas for the maxillary ridge, it amounted to 2.5 to 3 mm. He also showed that wide & unpredictable range of resorption pattern was found in patients 3-6 months after complete denture insertion.

Robert J. Crum and R. J. Loiselle (1972)[13] revealed that discrete sensitivity exists in the separate components of masticatory system. He also demonstrates the necessity for total integration of each component of the masticatory system and signals the importance of preserving the natural teeth.

Wayne R. Frantz (1975)[14] described the method of retaining minimal crown height for the abutment teeth with reduced friction and wear of the tooth or denture, and sufficient bulk for the denture base to avoid breakage.

Pacer and Bowman (1975)[15] studied the perception of occlusal loads in overdenture patients and found at load levels above 2,000 gm, the overdenture patients could discriminate loads better than patients with complete dentures.

Crum & Rooney (1978)[16] recognized that retaining of mandibular canines for over dentures helped to preserve the remaining edentulous ridge. An interesting finding was that patients with remaining canines lost less ridge height in region between the canines than those without any natural teeth, in the ratio of 1:8.

Stephen M. Parel et al (1983)[17] described the use of overdenture concept in rehabilitation of maxillofacial defects. The ultimate stability of any resection prosthesis will be obviously enhanced by the presence of healthy teeth used to counteract the dislodging forces of a disorganized occlusion.

K.Ogata et al (1988)[18] analysed the magnitude and direction of lateral forces exerted on the abutment teeth of lower complete overdentures and concluded that the periodontal structures can withstand heavy axial loading without damaging effects, whereas considerably lighter lateral forces may cause periodontal breakdown.

J.P. Ralph and R.M. Bhasker (1989)[19] described the role of overdentures in Gerodontics and indications for this particular approach such as

- Transition to the edentulous state
- Compensation for severe wear
- Additional support and positive retention for partial dentures

Ray A. Walters (1990)[20] described the preparation and design of abutments and factors to be considered in abutment selection such as location, angulation, relative height of the abutments to each other, margin placement, ability to house the attachment, path of draw, tooth and tissue undercuts, patient habits and maintenance of overdenture abutments.

Wennstrom et al (1990)[21] suggested that up to 70% of bone loss of the root length can be considered the limit for maintaining teeth in elderly patients, because the role of periodontal receptors for sensory feedback, discriminatory ability, and load sharing are important.

R. H. K. Batenburg et al (1998)[22] evaluated the effect of the number of implants supporting an overdenture on the condition of the peri-implant tissues and concluded that there was no need to insert more than two endosteal implants to support an overdenture, because of insignificant difference between the periodontal and radiographic parameters.

Ronald L. Ettinger and Fang Qian (2004)[23] conducted a study to identify the incidence and cause of tooth-loss in patients wearing overdentures and emphasized that the patient needs to be examined regularly to reduce the risk of experiencing caries and periodontal disease. Also, if the abutments are in the maxilla and are opposed by natural teeth, thimble crowns should be used to reduce the risk of vertical fractures.

Stefan Hug and Mericske- stern (2006)[24] compared the concept of combined root and implant supported overdenture with either exclusively root- or implant- supported overdentures and achieved similar results.

Takehisa Tanaka et al (2006)[25] suggested that a remaining tooth with a c/R ratio greater than approximately 1.5 should be used as an overdenture abutment tooth to minimse the lateral forces.

Carla Moreto Santos et al (2007)[26] demonstrated that the electromyographic activity of overdenture patients at rest and during postural position maintenance. The dentate individuals had smaller electromyographic values of masticatory muscles and the overdenture use caused electromyographic contraction patterns similar to those of dentate individuals in both positions.

Dostálová T et al (2009)[27] compared overdentures supported by natural teeth with ball attachments and that held by implants in a group of 35 patients (recall from 1 to 5 years). When subjectively and objectively assessed, no significant difference between both groups was observed.

ATTACHMENTS AND COPINGS USED TO RETAIN THE OVERDENTURES

The concept of attachments to retain overdentures dates back to well over a century.

Dolder E. J. (1961)[28] advocated the bar joint denture which is adapted primarily to the situation with few remaining teeth. The basic construction procedures consist of

1. Shortening and capping the residual teeth to render the crown: root length ratio more favorable
2. Splinting the abutments with a straight bar affixed to the cemented copings which serves, at the same time, as the bearing shaft for the complete denture.

Augsburger(1966)[29] cited that Hall and Gilmore described the bar splinted abutment teeth for supporting the complete denture. The Gilmore attachment paved way for attachment supported overdentures, approximately 60 years ago.

Prieskel (1967, 1968)[30,31] described about the various commercially available overdenture attachment systems and also described a composite impression technique for overdentures.

Merrill C. Mensor (1973)[32] advocated the use of E M attachment selector which consists of 8.5 by 11 inch color coded selector cards. It is compendium of attachments and connecting units available through out the world and it contains 30 points of information for each of more than 105 different attachment systems, this is a total of over 3000 points of information. Each of the cards numbered to correspond with 5 attachment classifications.

Joseph T. Quinlivan (1974) [33] said that retention is a problem for overlay dentures over simple copings when only two teeth remain, particularly, when treating a mandibular arch, which has a more limited basal seat area. He advocated RCT of the abutment teeth; pulp space to be enlarged with a Gates Glidden drill and finally with a safe sided para post drill. Then use of ball and socket type of attachment for overdenture, on the teeth reduced up to 1 mm above the gingiva.

A.B.Warren and A.A. Caputo (1975)[34] conducted a study to determine and compare the transfer of forces to the alveolar bone for five different abutment designs for the tooth supported dentures and concluded that there was a direct relationship between the stability and retention that each design provided and the amount of stress and torque transferred to the supporting structures. They found that Bischof – Disenbach and Ceka attachments generated greatest amount of torque under loads and short coping designs distributed more of the occlusal load on the ridge and less on the abutment. Attachments that used parallelism or undercuts for retention tend to produce the most severe stress conditions in the supporting alveolus.

George. L . Marquard (1976) [35] described a technique by using dolber bar joint mandibular overdentures for non parallel abutment teeth. Two techniques for attaching bar to the teeth with divergent root canals were used:

1. The schubiger screw system for those teeth with extremely divergent canals.

2. The stutz pivots system for teeth with only slight divergent root canals.

The use of bar joint offered periodontally involved teeth an improved crown – root ratio and splinting effect.

H.H.Thayer and A.A. Caputo (1979)[36] investigated the load transfer characteristics of different overdenture attachments such as tissue bar (Dolder bar, Hader and king connector) and stud attachments (Rotherman, Gerber and Ancrofix). They established a few guidelines for selection of specific overdenture attachments:

- The more retentive tissue bar and extra coronal attachments produced higher stress concentration.

- The posterior edentulous regions received some physiologic stimulation with the Dolder bar, for it shares more stress than the Zest anchor.
- The forces on the Dolder bar produce stress directed more apically so indicated for a short-rooted tooth with less supporting bone.
- The greater stress concentrated around the abutment teeth by the Zest anchor makes use of this design in periodontally sound tooth with long root structure well imbedded in supporting bone

Brett I. Cohen et al (1996)[37] measured the retentive force and the longevity of two precision overdenture attachment designs - a nylon overdenture cap system and a new cap and keeper system. Though, the nylon cap design required less force for removal, it showed more consistency in the force required over the course of the 2000 pulls when compared with the keeper with cap insert.

Labaig et al (1997)[38] proposed a classification to allow selection of correct treatment, after their photoelastic analysis of different attachment systems.

- Class I – Resistant abutment tooth and alveolar ridge – any design used with high rate of success.
- Class II – Weak abutment tooth and resistant alveolar ridge – stress breaker used to release the stress from abutment teeth.
- Class III – Resistant abutment tooth and weak alveolar ridge – rigid retention used
- Class IV – weak abutment tooth and alveolar ridge – most compromising situation. Any technique would have guarded prognosis, so alternative therapies considered.

Alberto J. Ambard et al (2002)[39] determined the cleansability of and patients' acceptance of overdentures retained by direct ERA attachments and overdentures supported by a Hader bar and found no significant difference between the two groups in terms of subjects' satisfaction and calculus, plaque and gingival index scores.

Kent T. Ochiai et al (2004)[40] studied the effect of palatal support on various types of implant-supported maxillary overdenture designs using photoelastic analysis. The results showed that the lack of palatal coverage demonstrated higher levels of stress around implants and visible supporting tissues than the different attachment designs tested.

Vygandas Rutkunas and Hiroshi Mizutani (2004)[41] evaluated the fatigue of five types of attachment like stud, Locator Root and magnets by measuring maximum retentive force and minimum number of cycles required to reach stable retention. Within the limitations of the in vitro study, stud attachments were more susceptible to fatigue than magnets and eight hundred cycles are required to achieve relatively stable retention of overdenture attachments.

Michael I. MacEntee et al (2005)[42] compared patients' satisfaction and prosthodontic maintenance of implant-retained mandibular complete dentures, whether reinforced or not with a cast framework, and attached by bar-clip or 2 ball-spring matrices to endosteal dental implants. The patients were satisfied with the dentures regardless of the attachment mechanism, and with or without a reinforcing framework.

Igor Chikunov et al(2008)[43] introduced implant-retained partial overdenture (IRPOD) with resilient attachments as a predictable and cost-effective treatment for partially edentulous patients. They also discussed the properties of the attachments and their advantages and disadvantages.

Ali Fakhry et al (2010)[44] measured the forces generated during the continuous seating and unseating of prefabricated spherical stud attachment systems with different angulations between the matrix-patrix components to retain implant overdentures. All the spherical stud attachments exhibited consistent seating and unseating forces over 10,000 cycles and even 20◦ angle between the patrix and matrix had no effect on the overall seating and unseating force values.

Swati Ahuja and David R. Cagna (2010)[45] described CBCT based implant diagnosis and treatment planning that will aid in 3-D visualization of available restorative space and its relationship to available osseous structures, supported by clinical fabrication of a radiographic template that accurately represents planned prosthesis contours, predictable implant placement and accurate definitive prosthesis fabrication.

MASTICATORY ABILITY AND BITE FORCE, ITS ASSESSMENT AND IMPLICATIONS

R. S. Manly and Louise C. Braley (1950)[46] calculated the masticatory efficiency from the number of chews required to reach a desired degree of food pulverization and the performance was found to be independent of the size of mouthful as long as the number of chewing strokes was kept constant.

Tooru Nagasawa et al (1979)[47] conducted an E.M.G. study to investigate the role of periodontal ligament in mastication in over denture patients. The tooth borne overdenture was superior to mucosa borne complete denture as far as masticatory efficiency and chewing skill were concerned.

G. Agerberg and G.E. Carlsson (1981)[48] evaluated the chewing ability of 1106 individuals by use of questionnaires and found that masticatory function was closely related to the number of residual teeth. Eight percent of the denture wearers considered their chewing ability to be poor; however, this finding was not reported by subjects with more than 20 natural teeth.

Heath M.R (1982)[49] reported that the masticatory effectiveness of complete denture wearers is only 16% to 50% that of dentate subjects.

H.S. Gunne (1985)[50] evaluated the masticatory efficiency with gelatin as test bolus combined with a dye absorption test and fractional sieving with almonds for the chewing tests and inferred that subjects with complete dentures and removable partial dentures compensated for a decreased masticatory efficiency by increasing the number of chewing strokes.

Venita J. Sposetti et al (1986)[51] analysed the functional advantages of use of attachments over conventional mandibular overdentures. Study showed that the bite force increased on an average of 50% from 50.8 to 76 lbs after placement of attachments and the EMG activity of the temporal and masseter muscles indicated greater biting strength and improved stability of the dentures in all phases of chewing.

Cecile G. Michael et al (1990)[52] concurred that the bite strength and masticatory forces in denture weare fell below the natural dentition range and the occlusal form of the posterior denture teeth did not significantly influence masticatory force.

Mahmood et al (1992)[53] compared masticatory efficiency of patients with immediate dentures and that of dentate individuals and experienced complete denture wearers by using image analysis and carrot as test food. Dentate subjects had significantly more efficiency than did complete or immediate denture wearers.

Slagter et al (1992)[54] examined the ability of 38 patients with complete dentures to comminute a tough artificial test food and compared it with the individual's chewing experience. They also found weak correlations between the chewing tests and the patient's own evaluation. It is probable that the self-assessment of chewing ability is in general too optimistic when compared with the results of functional chewing tests.

Kikuchi M. et al (1997)[55] said that the total maximum bite force generated with unilateral support was larger than with bilateral support and also there was an antero-posterior gradient of force with higher force being recorded at the posterior second molar region followed by the canine region, consistent with the lever theory.

Tsuga K et al (1998)[56] assessed the masticatory ability, dental state and bite force in 160 80-year-old persons and found that the edentulous persons (about one-fifth of all) reported more problems related to mastication than the other dentition groups. The maximal bite force varied much based on the number of remaining teeth and dental state. The self-assessed masticatory ability was weakly correlated with dental state and bite force and many subjects showed a good adaptation to an impaired dental status and small maximal bite force.

EA Fontijn-Tekampl et al (1998)[57] analyzed the effects of different degrees of support for the mandibular denture on bite forces measured four years after denture treatment. Results indicated that women had significantly lower maximum bite forces than men. Persons with mandibular implant-retained overdentures had significantly higher unilateral and bilateral maximum bite forces than complete-denture wearers. However, bite forces did not differ between the mainly implant-borne (TMI) and mucosa-implant-borne (IMZ) dentures.

F.A. Fontiin-Tekampl et al (2000)[58] demonstrated that the bite force levels achieved with overdentures on dental implants were between those achieved with artificial and natural dentitions and chewing efficiency was significantly greater than that of subjects with complete dentures, but was still lower than that of subjects with overdentures on bare roots.

J.P. Hatch et al (2001)[59] analysed the factors that affect the masticatory performance in adults and concluded that the number of functional tooth units and bite force were the key determinants of masticatory performance, which suggests that their maintenance may be of major importance for promoting healthful functional status.

van Kampen et al (2002)[2] found very small differences in maximum bite force and muscle activity obtained with magnet, bar-clip, and ball attachment which were statistically not significant and concluded that all superstructures significantly improved the oral function.

S. Okiyama et al (2003)[60] examined the relationship between masticatory performance and maximal occlusal force in dentate subjects, using gummy jellies with two different degrees of hardness and maximal occlusal force with pressure sensitive sheets. Masticatory performance was evaluated by increase of the surface area of expectorated pieces of comminuted gummy jelly that was calculated from the concentration of gelatin.

Yasutaka Ishikawa et al (2007)[61] investigated the color change of the chewing gum comparing to other methods while evaluating post-insertion changes of masticatory performance of complete denture wearers.

E. Yoshida et al(2007)[62] showed that subjects with greater maximum bite force and masticatory movement pattern with greater vertical amplitude, less angle of closing path and shorter duration in closing phase have greater Mixing ability indices when the two-coloured paraffin wax was used.

K. Fueki et al (2008)[63] were not able to find any significant correlation between the activity of jaw-closing muscles during chewing the wax cube and the food mixing ability except for a muscle work of 28% on chewing side was identified to account for interindividual variation in MAI.

Mert Uc Ankale et al (2010)[64] measured the maximum bite force and electrical activity of masseter muscle in 35 edentulous patients before and after attachment retained implant-supported overdentures and there was significant increase in all the subjects. They used a silicone block on the contralateral side, while measuring the bite force to prevent tipping of the maxillary denture.

MATERIALS AND METHODS

STUDY DESIGN :

This clinical study was performed to compare, quantitatively, the oral function, namely the maximal bite force and masticatory performance of three groups of subjects with (a) complete dentures (b) overdentures with ball and cap attachment and (c) overdentures with bar and clip attachment. Furthermore, correlations between maximum bite forces and chewing efficiency were investigated. A group of subjects with complete-natural dentition were taken up for this study to compare the bite force and masticatory efficiency with complete denture and overdenture wearers. This study was performed from December 2010 to November 2010 in the Department of Prosthodontics, Tamilnadu Government Dental College and Hospital, Chennai.

ETHICAL COMMITTEE APPROVAL:

The study was conducted with the approval from the institutional ethical committee.

The following materials and equipments were used to conduct the study:
ARMAMENTARIUM FOR CLINICAL EXAMINATION:

1. Kidney Tray
2. Mouth mirror
3. Periodontal probe
4. Cheek retractor
5. Disposable gloves and mask

ARMAMENTARIUM FOR TOOTH PREPARATION:

1. Airotor handpiece
2. Coarse and Fine Diamond points – flat-end tapering, round-end tapering, flame shape
3. Gates glidden Drill – sizes 1 to 6
4. Peeso reamer – sizes 1 to 6

ARMAMENTARIUM FOR FABRICATION OF COMPLETE DENTURE

1. Alginate – Chromalgin
2. Maxillary and Mandibular stock trays
3. Type III dental stone (Kalstone)
4. Type II Dental plaster
5. Green stick compound (Samit)
6. Putty addition silicone impression material (Ivoclar, Vivadent)
7. Light body addition silicone impression material (Ivoclar, Vivadent)
8. Tray adhesive (Ivoclar, vivadent)
9. Type IV dental stone (Ultrarock)
10. Dentatus face bow and Articulator
11. Acryrock Teeth set
12. DPI Heat cure

ARMAMENTARIUM FOR FABRICATING ATTACHMENT RETAINED OVERDENTURES:

1. Castable pivots for canal impressions (normal - 2.5 mm, micro – 1.8 mm)

2. Castable spheres (normal – 2.5 mm and micro – 1.8 mm)
3. OT CAP retentive caps – white, pink, yellow, green and black caps (for lab use) - normal and micro size
4. Castable OT BOX CLASSIC (normal and micro size)
5. Castable OT BOX Connectors
6. Plastic Positioning rings (normal and micro size)
7. Castable bars
8. Retentive clips – pink and yellow
9. Parallelometer and its keys for OT CAP and OT BAR MULTIUSE
10. Insertion tool for OT CAP (normal and micro size)

ARMAMENTARIUM FOR EVALUATING THE BITE FORCE

1. Bite force meter – strain gauge transducer
2. Mouth prop
3. Surgical Gloves
4. Surgical spirit

ARMAMENTARIUM FOR EVALUATING THE MASTICATORY PERFORMANCE:

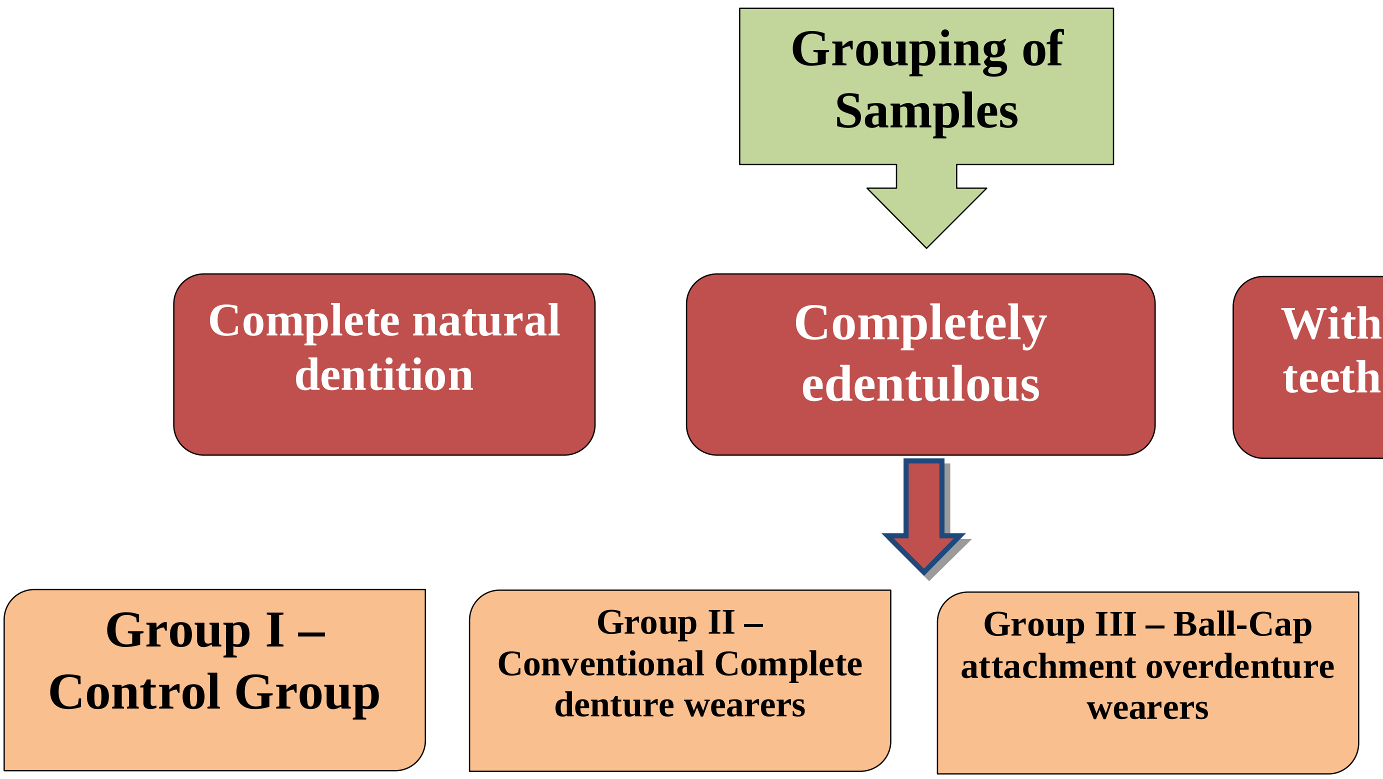
1. Paraffin wax test food
2. Die for preparing the test food, made of mild steel
3. Canon EOS 5D Mark II: 21Mega Pixels with macro lens
4. Ring Flash
5. Adobe Photoshop
6. Auto CADD software

S.No	NAME (commercial name)	FORM OF THE MATERIAL	MANUFACTURER DETAILS
1.	Vignette chromatic alginate impression material	Irreversible hydrocolloid impression material	Dentsply, India
2.	Jabbar trays	Stock tray	Jabbar &co,India
3.	Kalstone	Type III Dental stone	Kalabhai,India
4.	Virtual Tray Adhesive	Tray adhesive	Ivoclar Vivadent,USA
5.	Virtual Putty and light body	Putty and light body addition silicone impression material	Ivoclar Vivadent,USA
6.	Ultrarock	Type IV dental stone	Kalabhai, India
7.	Acralyn H	High impact heat cure resin	Asian Acrylates, India
8.	Bite force meter - Strain gauge transducer	Strain gauge transducer	Indigenously designed Hitech equipments, Bangalore
9.	Ball - cap attachments	Castable components	Rhein 83, Bologna, Italy
10.	Bar -clip attachments	Castable components	Rhein 83, Bologna, Italy
11.	Mouth prop	Mouth prop – 5 sizes	Sirag surgicals, Chennai
12.	Sasolwax 7835	Paraffin wax – food grade	Durga Products, Chennai
13.	Metal die	Mild steel	Indigenously designed, Senthil Lab works, Chennai
14.	Adobe photo shop	Software	Apple, USA
15.	AUTOCAD	Software	Apple, USA

METHODOLOGY:

1. SUBJECT SELECTION:
2. PREPARING STUDY MODELS AND DIAGNOSTIC MOUNTING
3. SELECTION OF ABUTMENTS AND ATTACHMENTS
4. TOOTH PREPARATION AND MAKING SECONDARY IMPRESSION
5. JAW RELATION RECORDING AND WAX TRY-IN
6. FABRICATION OF ATTACHMENTS AND DENTURE INSERTION
7. EVALUATION OF BITE FORCE USING STRAIN GAUGE TRANSDUCER
8. EVALUATION OF MASTICATORY EFFICIENCY USING WAX TEST FOOD
9. METHOD OF STATISTICAL ANALYSIS

STUDY DESIGN



Subject Selection :

Study participants were selected from among the out patients at Department Of Prosthodontics, Tamilnadu Government Dental College and Hospital. The patients selected for this study were categorized into 4 groups based on the oral condition and the restorative procedure.

Group 1 - Complete natural dentition

Group 2 - Completely edentulous

Group 3 – With four or less retainable teeth in the mandibular and maxillary arch - Overdentures fabricated with ball and cap attachment

Group 4 – With four or less retainable teeth in the mandibular and maxillary arch - Overdentures fabricated with bar and clip attachment

The study participants with few teeth remaining having minimum bone support of 7 mm, which are indicated for total extraction were selected for over denture therapy. All the patients were similar in terms of age between 45 – 60 years. The dentate group was recruited as those healthy subjects with 28 teeth, without any restorations, and with normal occlusion. All the patients were informed about the purpose and methods of the study and signed the written consensus.

The **inclusion criteria** for entry into the trial were:

(a) Medically fit enough to undergo the treatment procedure like extraction and endodontic treatment;

(b) Healthy oral mucosa,

(c) Class I jaw relation,

(d) Adequate denture space,

(e) Suitable abutment teeth,

(f) Good oral hygiene,

(g) Co-operative attitude and motivation

The **exclusion criteria** were:

(a) Presence of temporomandibular disorder,

(b) Bruxism,

(c) Systemic and/or neurological disorders

(d) Smoking habits

(e) Highly resorbed ridge

(f) Soft tissue disorders,

(g) Chronic tissue trauma, poor tissue support for dentures,

(h) Those who could not chew with their dentures.

DIAGNOSIS AND TREATMENT PLANNING:

All the patients underwent the stomatological examination and the following pathologies were observed: periodontitis, stomatitis, root caries and increased mobility of some abutments. Oral hygiene maintenance was checked and patients with poor oral hygiene were obliged and motivated to improve their hygienic habits.

INVESTIGATIONS:

Orthopantomogram and periapical radiographs were taken for assessment of bone suppo rt and endodontic evaluation.

CLINICAL STEPS INVOLVED :

Preparation of study models :

Maxillary and mandibular arch impressions were recorded with irreversible hydrocolloid and casts poured with type III dental stone. Bite registration was done with aluwax and mounted in mean value articulator.

Diagnostic casts were mounted, for selection of abutments, positioning of teeth, jaw relationship, available denture space, tissue undercuts.

SELECTION OF ABUTMENT TEETH :

Periodontal Considerations :

- Minimum of 7mm of alveolar bone support should be present radiographically
- Periodontal disease of individual tooth is classified based on the guidance proposed by **Lindhe and Nyman (1975)**[C1]**,** according to which the periodontal status is classified into gingivitis (G), early periodontitis (P1), moderate periodontitis (P2), and severe periodontitis (P3).
- Mobility of teeth is classified into Grade I,II ,III, & IV .Abutment with severe periodontitis (P3) and grade III & grade IV mobility are advised for extraction and not included in the study
- Probing depth of not more than 3 mm around the abutment teeth
- Adequate zone of attached gingiva is needed for the periodontal health of the abutments, about 3mm is the minimal requirement

Endodontic Considerations :

- E

  n

  dodontic status of the abutments was assessed using intra oral radio graph.

- Abutment teeth with periapical pathology like perapical abcess, perapical granuloma, perapical cyst were advised for extraction and not included in the study

- Endodontic therapy was performed on all abutment teeth in order to obtain a more favourable clinical crown – root ratio.
- Abutments that are fit both endontically and periodontally were selected and root canal therapy was done at the Department of Operative Dentistry and Endodontics, TNGDC&H.

Diagnostic casts which were mounted in mean value articulator was assessed for selection of attachments. Fabrication of an over denture with attachments requires minimum of 20 to 30 mm of interarch space .

SELECTION OF ATTACHMENTS :

The two attachments that were used in this study are the commercially available Rhein’83 precision attachments.

Ball and cap **Bar and clip**

The attachments were selected based on the periodontal status and the crown – root ratio of the two abutment teeth. If one tooth is weak, the ball and cap attachment allows independent movement and the stronger tooth can serve as the fulcrum point for movement of the weaker tooth in the prosthesis. Whereas the bar and clip has a splinting effect and rigidly fixates the prosthesis, therefore all or none of the teeth movement occurs under a functional load[65].

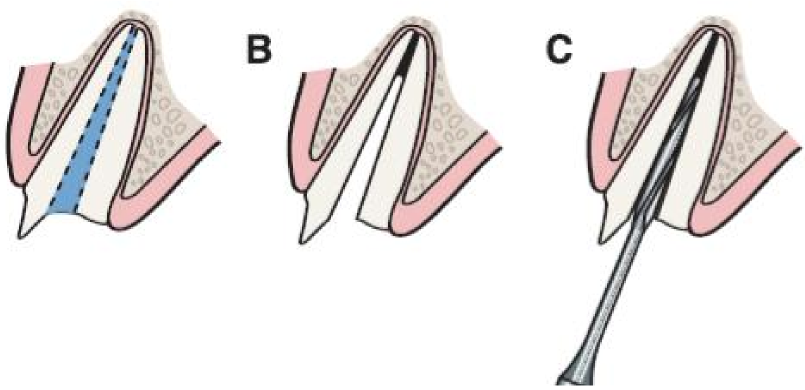
FABRICATION OF ATTACHMENT RETAINED OVERDENTURES:

BALL AND CAP ATTACHMENT RETAINED OVERDENTURE

Preparation of post space and impression technique:

Preliminary impression of maxillary arch was recorded with impression compound using edentulous stock tray. Preliminary impression of mandibular arch with the abutment for overdenture was recorded with irreversible hydrocolloid using dentulous stock tray, cast was poured with type III dental stone. Custom tray was fabricated with autopolymerising acrylic resin, border molding of maxillary arch was made with tracing stick and impression was made with zinc oxide eugenol.

Border molding of mandibular arch was done with addition silicone of putty consistency. Clinical crown of the abutment tooth was reduced to the level of the gingival margin, leaving 2-3 mm of tooth structure above the gingiva, with a chamfer finish line, incorporating cervical ferrule and antirotation groove. Guttapercha (GP) was removed from the root canal using H files leaving the apical third intact and IOPA was taken to confirm the presence of GP at the apical region. Coronal orifice was enlarged using gates gliden drill (available in sizes 1 to 6) and post space was prepared using peeso reamer (available in sizes 1 to 6).



Prefabricated Impression post was used to record the impression of the post space. The prefabricated posts are available in two different sizes - micro (diameter of the sphere - 1.8 mm) and macro (2.5 mm diameter) and different lengths (7, 9,10,12,14 mm for macro and 7, 9, 10 mm for micro).

Addition silicone of light body consistency was coated in to the post space using lentilospiral, the impression post was coated with tray adhesive and placed into the post space, the border molded custom tray was loaded with light body and placed in to the mouth and allowed to set. The impression post placed in the post space was picked up by the impression. The impression was boxed and two casts were poured, one was poured in Type III dental stone, for processing the denture and other was poured in type IV dental stone, to make the wax pattern for Richmond crown.

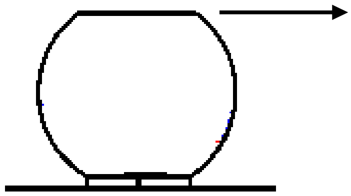
Jaw relation recording and Wax try in:

Maxillary and mandibular record bases were made with autopolymerising acrylic resin and occlusal rims were prepared using modeling wax. Orientation jaw relation was done with arbitrary face bow and the maxillary cast was transferred to the semiadjustable articulator (Dentatus). Vertical jaw relation was established, horizontal jaw relation was done by gothic arch tracing and centric and protrusive records were made using Type II Gypsum product. Teeth were arranged in balanced occlusion and tried in the patient's mouth.

Fabrication of wax pattern for Richmond crown:

The prefabricated castable sphere (Rhein 83) was used to make the Richmond crown. They are available in two sizes, normal (2.5 mm diameter) and micro (1.8 mm diameter), also colour coded as green and red respectively.

The castable sphere has a leveled head which provides space between the retentive cap and the sphere and also reduces the stresses during vertical flexion.



This ball and cap attachment provides retention by elastic means and allows movement of the denture, thereby resulting in a prosthesis which is resilient and shock absorbing.

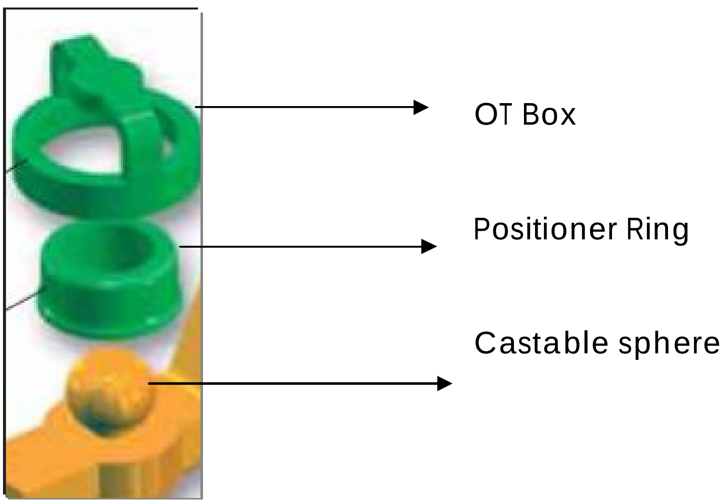
The prefabricated attachments are placed over the wax pattern using the Parallelometer with the respective keys for normal and micro sizes. Parallelometer is a mini surveyor used to find the correct horizontal position on the stone model using the swiveled base. The attachment mandrel was locked in place inserting it onto the notch on the movable extension arm and the locking screw tightened. The movement of the extension arm was monitored and the rear locking screw tightened. Parallelometer keys of normal and micro size were used to hold the attachment and orient it to the wax pattern.

The teeth set up of mandibular trial denture was transferred to the second cast which was made in Type IV dental stone and placed on the parallelometer . The swiveled base

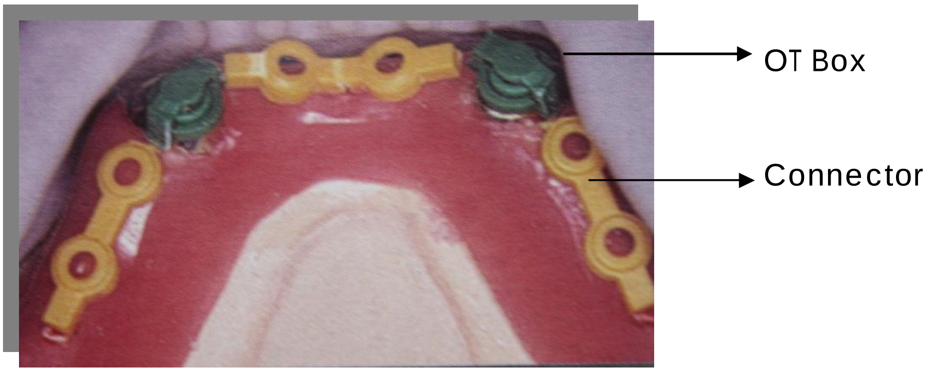
lockin

g nut was released so that the locking attachment for the mandrel could be moved up and down, front and back. The parallelism between the occlusal plane and the swiveled base was established such that the arm of the mandrel touched the acrylic teeth of both sides at the same time. The corresponding position of the swiveled table was locked and the cast removed from the table. Impression post which was used to record the post space were placed into the post space. Abutment teeth on the cast were lubricated, wax pattern made over the post and transferred to the parallelometer which was locked in a position parallel to the teeth set up. The attachment was locked in the key and placed over the wax pattern and luted with wax. The locking key was released and the wax pattern with the post, core and ball attachment on the top (Richmond crown) was made.

Sprue of 2 mm diameter was attached, invested and cast with cobalt chromium alloy in centrifugal casting machine. The cast Richmond crown was sand blasted and trimmed with care without damaging the attachment. The attachment was glass blasted and polished with rubber wheels and rouge .The polished crown was placed on the cast and the fit verified. Then, fabrication of reinforcement frame work was carried out. Positioner ring of the corresponding size (normal or micro) of the attachment was placed over the Richmond crowns.



Castable housing (OT box mono - micro or normal) was placed over the positioner ring, mesial and distal parts of the castable housing were connected by castable connector using pattern resin. The entire frame work was lifted from the



cast, the positioner ring being retained on the Richmond crown. The frame work was sprued with 4mm diameter sprue and cast with cobalt chromium alloy.

The elastic caps are available with different retention degrees, in different sizes and are colour coded. Black color for laboratory purpose, yellow color for very elastic retention (normal size - 500 to 550 g, Micro size - 450 to 500 g), pink cap offers elastic retention (normal size - 800 to 950 g, micro size - 750 to 850 g), white cap offers standard retention (normal size - 1200 to 1300 g, micro size - 1000 to 1100 g)

The black elastic cap was inserted into the cast frame work using the insertion tool provided from the manufacturer and seated on the Richmond crown and the fit was verified over the cast one. The teeth set up of the mandibular trial denture was indexed with laboratory putty, teeth were removed from the set up and positioned over the index.

The entire assembly of putty index and teeth was placed on the cast which is having the Richmond crown with reinforcement frame work. Acrylic teeth were trimmed to provide space for the acrylic resin, wax up was done and occlusion checked with the opposing trial denture. Flasking and dewaxing was done, light body addition silicone was coated in to the post space in the cast two, Richmond crown along with the frame work was stabilized over the cast to prevent the movement of the prosthesis. Acrylic resin was packed in to the mold and polymerized. Denture was removed from the flask, trimmed and polished well. The maxillary and reinforced mandibular dentures along with the Richmond crowns were ready for insertion.

Insertion of Richmond crown and Denture:

The black cap on the frame work was removed and a retentive cap other than the black was inserted in to the housing. Richmond crown was placed in the prepared tooth and the fit was verified, the lower denture with the retentive cap was placed over the Richmond crown, occlusion was checked with maxillary denture in place. The mandibular denture was removed from the mouth along with the Richmond crown being picked up. Zinc phosphate luting cement was mixed, post space and the Richmond crown were coated at the same time, the entire assembly was placed in the mouth, maxillary denture was inserted and the occlusion assessed. Patient was instructed not to remove the lower denture for 24 hrs and asked to come for review. On review, when the maxillary and mandibular dentures were removed, the Richmond crowns would be fixed to the prepared abutment teeth and the retentive caps are present in the impression surface of the mandibular denture.

In cases, where the interarch distance was less than 25 mm, mandibular overdentures without reinforcement were made. Laboratory steps for making the denture were similar to the fabrication of denture with reinforcement. The black cap in the denture was removed from the processed denture and a hole was made correspondingly. Richmond crowns were placed in the mouth, retentive caps placed over the crown and the denture seated in the mouth. The cap was seen through the hole and the occlusion was checked with the opposing maxillary denture. Retentive caps were placed over the Richmond crowns and lower denture was inserted, autopolymerizing acrylic resin was mixed and placed in to the hole and allowed to set. On removal, the Richmond crown was picked up along with the mandibular denture. The crown was removed from the denture, excess acrylic resin was trimmed, crown was seated in the denture and again occlusion was checked. Zinc phosphate cement was mixed and coated on the post space and crown simultaneously and the entire assembly was placed in the mouth. The patient was advised not to remove the lower denture for 24 hrs and recalled for review. The mandibular denture was removed and the excess cement cleaned and instructions given.

FABRICATION OF BAR AND CLIP RETAINED OVER DENTURE

Preparation of the abutment:

The periodontal and the endodontic status of the abutment teeth were assessed as per the guidelines discussed earlier, intentional endodontic treatment was done for the abutment teeth. Preliminary impression of the mandibular arch was recorded with irreversible hydrocolloid using dentulous stock tray. Custom tray was fabricated using autopolymerising resin.

The abutment tooth was reduced and prepared with chamfer finish line, with an occluso-gingival height of minimum 3 to 4 mm to provide resistance and retention form. The custom tray was seated in the patient's mouth, extensions were checked, border molding done with addition silicone of putty consistency and final impression made with light body consistency of addition silicone. Two casts were poured using the impression, first cast was poured with type III dental stone for processing the over denture, second cast was poured with type IV dental stone for making the wax pattern of castable bar .

Jaw relation recording and Wax try in:

The procedures of jaw relation and wax try in were performed in a usual manner.

Fabrication of wax pattern for the Castable bar:

Castable bar (RHEIN 83) was used in the fabrication of bar and clip retained over denture. The bar is convex on one side and flat on the other side .Convex side when placed up and flat side placed facing the alveolar ridge (version A) offers rigid retention whereas flat side facing up and the convex side towards the residual ridge (version B) offers resilient retention. Special key for parallelometer is available to orientate the bar to the wax patterns on the abutment teeth. Version A, rigid retention mode was used for all the cases in this study.

The trial denture from the first cast was transferred to the second cast and the parallelism was established using the parallelometer as it was described for the ball and cap attachment procedure. The key for the parallelometer was used to fix the bar to the wax pattern, 2mm sprue was attached and casting done in cobalt chromium alloy. Trimming and polishing was done as per the earlier procedure.

The retentive clip is available in two colors pink (soft retention) and yellow (medium retention). The bar with the retentive clip was placed over the first cast, space for the acrylic resin was assessed and acrylic teeth were trimmed using the putty index as discussed earlier. The dentures were processed and the mandibular denture with the cast bar was ready for insertion.

Insertion of the Denture and Coping with Bar:

The coping with the bar was placed on the prepared tooth and the fit verified. The mandibular and maxillary dentures were inserted and occlusion assessed. The coping along with the bar was cemented using glass ionomer cement and the patient was recalled after 24 hrs. Retentive clip was placed over the bar, auto polymerizing acrylic resin was used to fix the clip, it was allowed to set and the denture removed from the mouth. The retentive clip placed on the bar would be picked up by the denture. Post insertion maintenance and instructions were given to the patient.

EVALUATION OF BITE FORCE:

Bite force is measured by determining the strain which is the degree of deformation due to the stress or load applied to the strain gauge. When a material is compressed, the force used generates a corresponding stress which in turn generates a proportional compressive strain which deforms the material by L +/- ^L, where L is the original length of the material and the ratio of ^L to L is called strain. The strain gauges consist of a semi- conductor material and measure the resultant strain to the corresponding electrical resistance changes in the strain gauge material, on application of external load.

Strain gauge Configuration:

In this study, the stain gauge transducer was constructed by bonding a fine electric resistance wire i.e. paralleled vinyl lead wire of 15mm long, laid in a zigzag manner, to a compensating material – Aluminium 2024-T4, which is an electric insulation base. Epoxy resin was used as bonding material and 3 mm thick butyl rubber was coated as a protective layer. The gauge has a length of 15mm, width of 3 mm, resistance of 350 ohms, and gauge factor 2.14%. The strain gauge transducer was sensitive upto a maximum force of 400 N. Self-temperature compensated gauges were used to minimize the gauge thermal output when bonded to the dual beam transducer, made of Aluminium, that has a specific linear co-efficient of thermal expansion in the specified temperature range. The strain limit i.e. the allowable elongation percent was 150% more than the maximum force it could withstand. The number of repeated cycles that the gauge can endure (fatigue life) was 1×10^5 cycles

The theory of strain gauges was based on the fact that elongating a metal element such as a wire will change in resistance. When strain was generated in the dual beam transducer, it was relayed via the gauge base (electrical insulation) to the resistance wire in the gauge. As a result, the fine wire experienced a variation in electrical resistance, which was exactly proportional to the strain. Since this resistance change was very small, a Wheatstone bridge circuit was required to convert it to voltage output.

Load application on the dual beam transducer → Transfer of strain to the strain gauge

↓

Deformation of the strain gauge

↓

Change in electrical resistance proportional to the strain

↓

Quarter bridge circuit detects the voltage output

↑

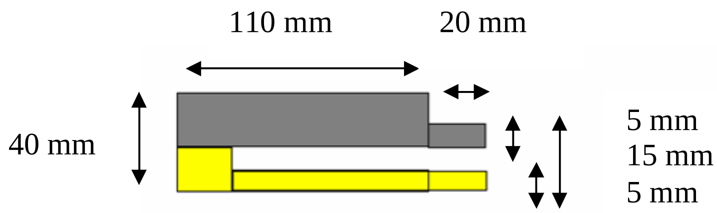
Proportional to the strain produced

↑

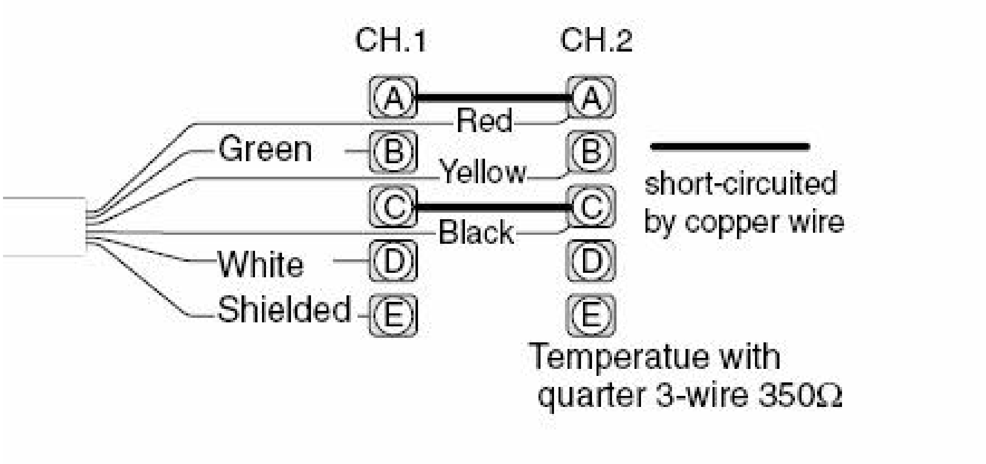
Load application on the dual beam transducer

The strain gauge was connected to a static strainmeter, which provided the Wheatstone bridge circuit and exciting input voltage. The strain (Ε) was measured on the digital display.

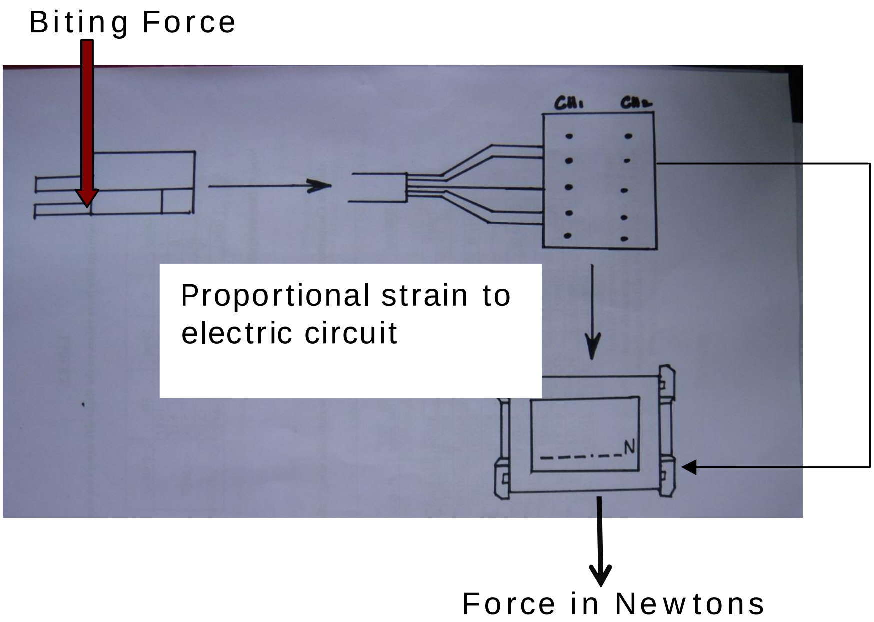
DIMENSIONS OF DUAL BEAM TRANSDUCER



ELECTRIC CIRCUIT OF STRAINMETER



SCHEMATIC REPRESENTATION OF BITE FORCE MEASUREMENT



Methodology for measuring the Unilateral maximum bite force:

Patient preparation:

The bite force was measured in the subjects after a period of 1 month, so that the patients were used to the dentures. Patient was seated in upright position in dental chair, keeping the maxillary occlusal plane approximately parallel to the floor. The dual beam transducer was also maintained parallel to the maxillary denture and evaluated intraorally for proper position and comfort. Patients were trained before test to create confidence and instructed to bite on the bite force meter with their maximum force.

Micro strain recording:

The experiment started with no load, where strain value was nil. The dual beam transducer was positioned at the first molar and second premolar region and the patient was instructed to clench hard for 2 seconds. Once the load was completely applied, readings of the strain gauges were taken in micro strain units from the digital multi-channel strain indicator. The measurements were repeated once with a one-minute rest and the highest of the two readings were noted down for each patient. The maximum bite force was tabulated for right and left sides separately.

A mouth prop of the same height as that of the dual beam transducer was placed on the opposite side for occlusal stability of the maxillary complete denture. The same procedure was repeated on the other side by interchanging the dual beam transducer with the mouth prop.

For the dentate groups, the teeth were protected by covering on both the sides of the transducer with 1.5- mm-thick putty addition silicone bonded by tray adhesive. The dual beam transducer was covered with surgical glove while inserting it in the patient's mouth as a part of sterilization and also cleaned with ethyl alcohol, after each use.

EVALUATION OF MASTICATORY PERFORMANCE :

Preparation Of Test Food :

Food grade fully refined paraffin wax (Sasolwax 7835) with melting range of 56 – 74 ^{o}C was used along with 20% of liquid paraffin so as to make it more softer and less brittle. They were melted together and divided into equal halves. Red and green food colorants were added and stored at 37 ^{o}C.

Preparation of Test Cubes:

A die was made of mild steel (MS) with a mould space of dimension 2 x 2 x 10 mm. The die had three parts, with holes and pins to approximate them correctly, each time after pouring the wax into the mould space.

Small cuboids having the identical dimensions of 2 x 2 x 10 mm were made from the molten paraffin wax which is dyed either red or green. The red cuboids and green ones were put together side by side to produce a sheet of 10 x 10 x 2 mm with only different colour cuboids touching each other. Five identical sheets were stacked together so that a standard cube of 10 x 10 x 10 mm was obtained with alternating colors. The paraffin cubes were stored at 37 ^{o}C till just before the tests were performed. Therefore, the cubes maintained their constant properties and also not very hard for the patient to chew.

Masticatory Performance test:

The subjects were instructed to chew the test food well either on the right side or on the left or on both, as preferred by the subject (habitual chewing) for 10 strokes and to expectorate the bolus of masticated test food from their mouths on a sheet of gauze as thoroughly as possible. The collected paraffin wax was washed with running water for 30 seconds to remove the saliva. The temperature of the water was also 37 ^{o}C, to prevent the contraction of the paraffin wax.

After chewing the paraffin cube, a deformation of cube, i.e. a chewed test cube was obtained. The chewed test cubes were treated as samples for evaluating the masticatory performance. The samples were managed by means of digital image processing. From the images, the information of colour mixing and the shape of the sample were acquired.

Digital image analysis:

Digital images of the samples were captured using a Canon Digital EOS 5D – 21 Mega pixels with high performance DIGIC 4 series to produce accurate white balance, thereby improved image quality. The Canon EF 100mm f/2.8 USM (Ultra sonic motor lens) Macro Lens was used so as to get an image of magnification 1:1 (i.e. nil magnification). The images were taken under the illumination of ring flash where the origin of the light is very close to (and surrounds) the optical axis of the lens, so that shadows visible in the photograph were minimized. For objects close to the camera as in dental photography, the size of the ring flash is significant so that the light encountered the subject from many angles in the same way with that of a conventional flash with soft box. This has the effect of further softening any shadows and there was no need to flatten the samples. Images of the samples at both sides were taken, since they had differences with regard to the degree of colour mixing.

IMAGE ANALYSIS:

- Tracing Software (Auto CAD) that is used to trace elevation photographs was used to trace the photograph.
- Since AutoCAD works on a universal scale, (i.e. it doesn't have any dimensions until it is fed in it) the spat out wax material was photographed with a millimeter scale to give a reference dimension, so as to bring the photo to scale.
- Once the photograph was brought to scale, the dimensions were traced and measured in millimeters.
- Colour identification was done using Adobe photoshop, so as to select similar colored regions in a photograph. Areas which were not completely mixed were identified using this software, with the help of colour intensity defined from the image of unchewed test food, which was captured under similar lighting conditions.
- The thresholds for minimum red and green coloured area was taken as 1 mm^2 and the colour intensity to define red area (RA) and green area (GA) were identified from the unchewed wax cube.
- Using Magic Wand (tool in Adobe photoshop), the region with pure red was clicked, and all the regions with pure red were selected in the photograph. This enabled to mark out these regions and their respective dimensions were measured with AutoCAD
- The measurements calculated using the image analysis were Red area (RA), Green area (GA), Total area (A), Area above 1 mm in thickness (AH), Maximum length (ML) and Maximum breadth (MB).
- The following parameters were calculated from these measurements.

- **MIX** = 100 – (RA+GA)/A * 100 (**The ratio of colour mixed area)**
- **TR** = 100 – A/AH * 100 **(The ratio of area above 1 mm in thickness to total projection area)**
- **LB** = ML/MB (**LB: The ratio of maximum length to maximum breadth)**
- **FF** = ML^2 * Pi/4 * AH * 100 (**The shape factor shows how flat the sample is)**
- **The Mixing ability Index (MAI)** = 1.360 * 10^{-1} * Mix + 2.950 * 10^{-1} * (TR) + 3.584 * 10^{-3} * (LB) - 2.032 * 10^{-3} * (FF) + 7.950 * 10^{-4} * (AH) – 12.62

Classification of samples :

The samples were classified into three groups by visual inspection of degree of colour mixing condition. Classification criteria into each group were as follows :

Good group - There were almost mixed region in the sample.

Medium group - Area of mixed region was almost equal to area of unmixed region in the sample.

Poor group – Both the colours almost remained unmixed in the sample.

METHODS OF STATISTICAL ANALYSIS:

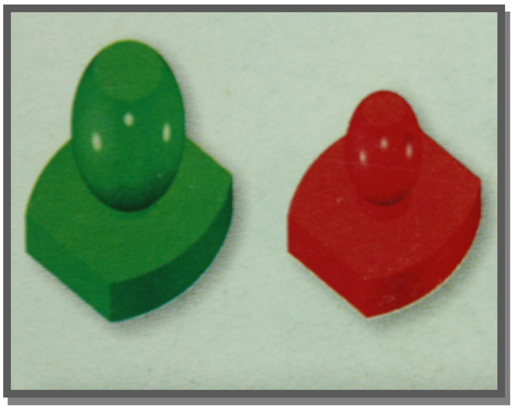
The overall group comparison was done using one way ANOVA followed by Tukey's HSD Post Hoc tests. The Right and left side bite force levels were compared using Paired T- test.

PHOTOGRAPHS

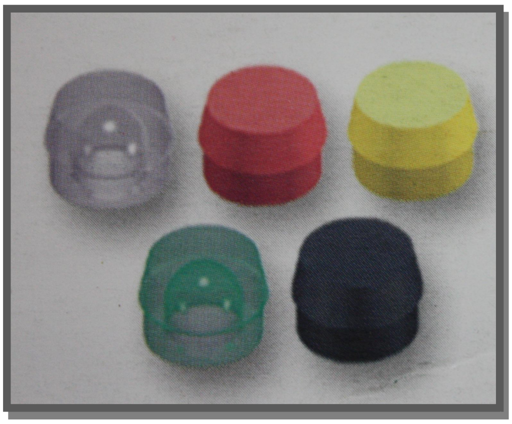
ATTACHMENTS – COMPONENTS AND TOOLS USED IN THIS STUDY

IMPRESSION POSTS NORMAL AND MICRO

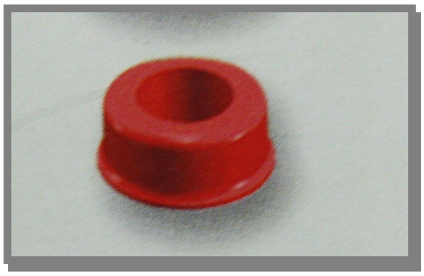
CASTABLE SPHERES NORMAL AND MICRO

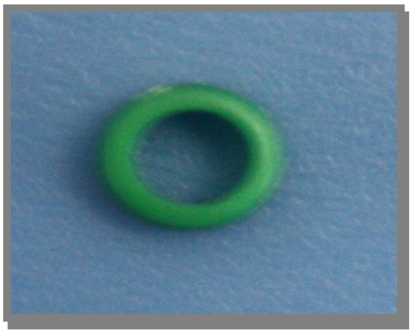


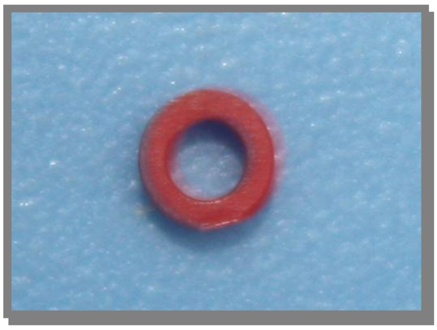
OT CAP – RETENTIVE CAPS



POSITIONING RING

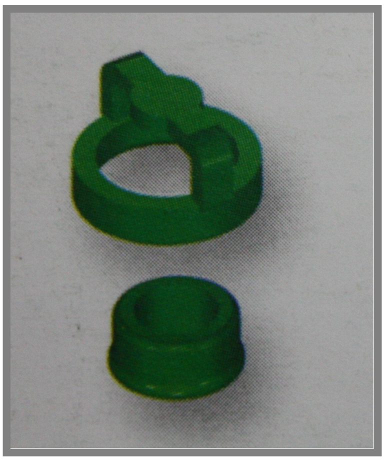


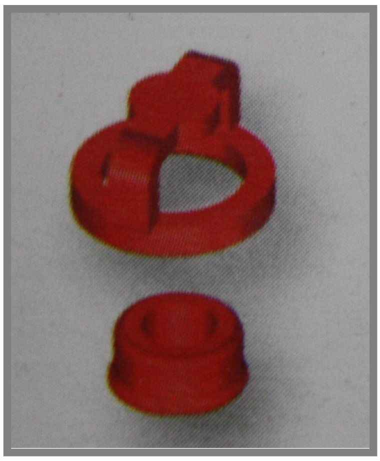




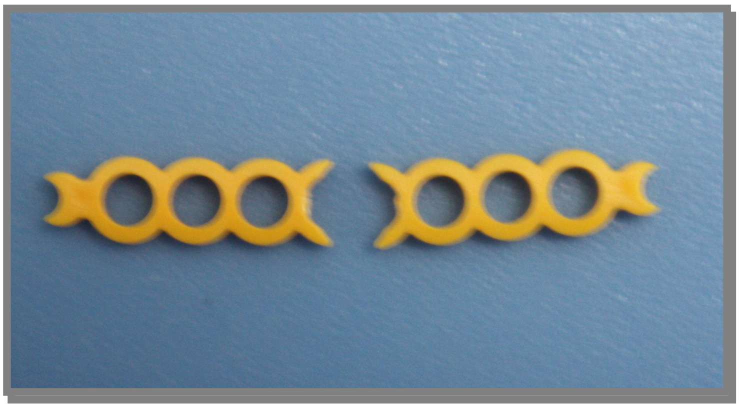
NORMAL SIZE MICRO SIZE

CASTABLE HOUSING – OT BOX CLASSIC



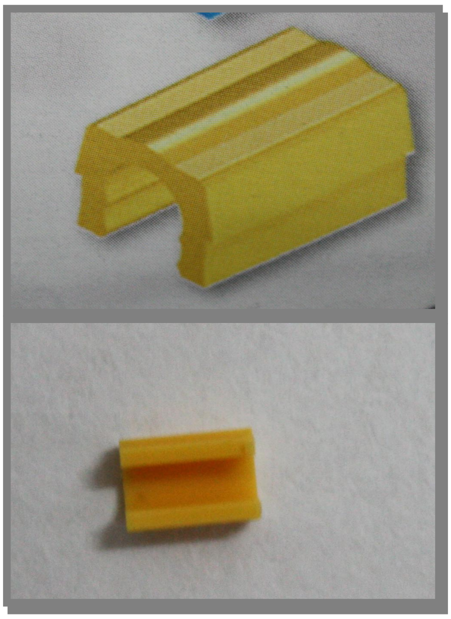


CONNECTOR

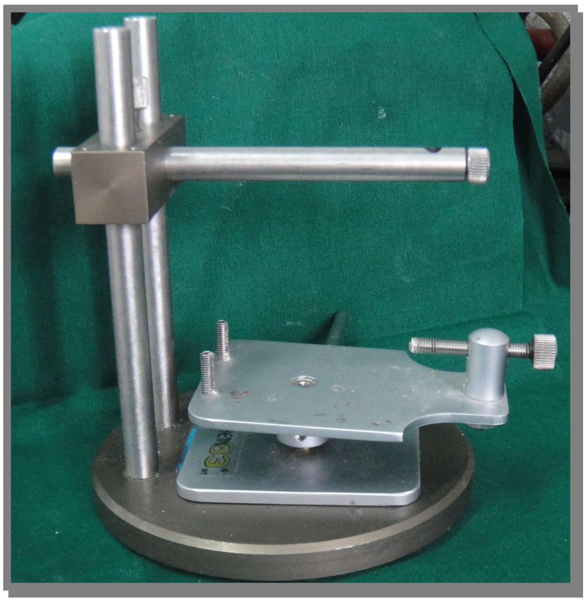


CASTABLE BAR

RETENTIVE CLIP



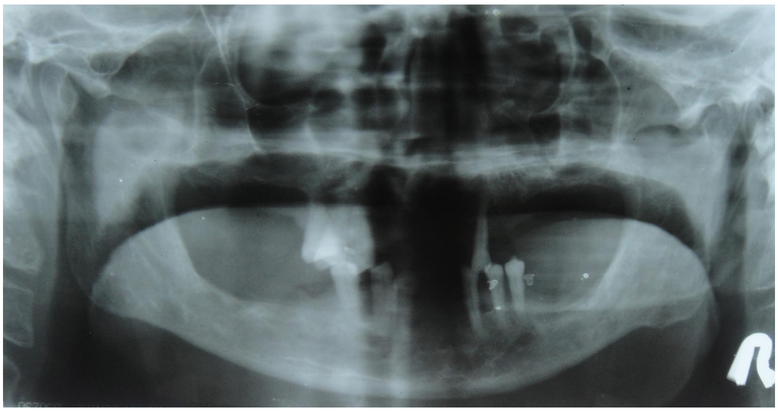
PARALLELOMETER



INSERTION TOOLS FOR CASTABLE SPHERE AND BAR

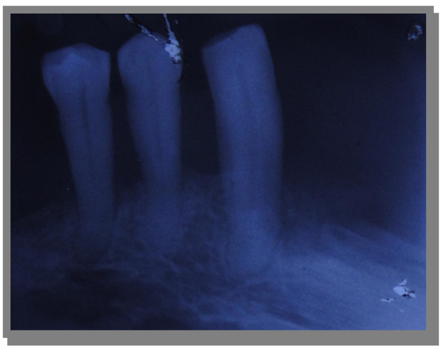
INSERTION TOOLS FOR ELASTIC CAP

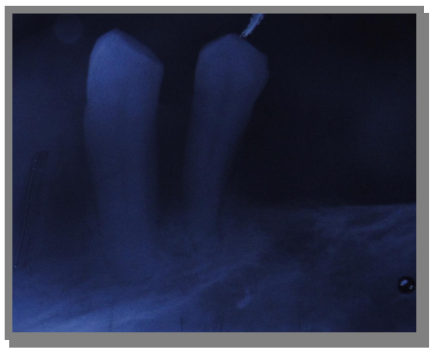
PREOPERATIVE STATUS



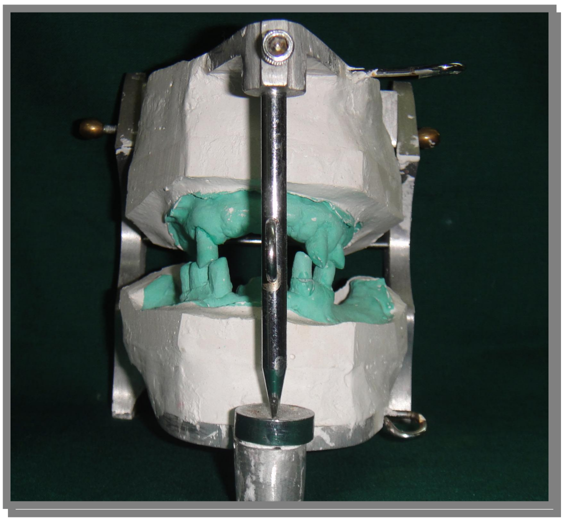
PANOROGRAM

INTRAORAL PERIAPICAL

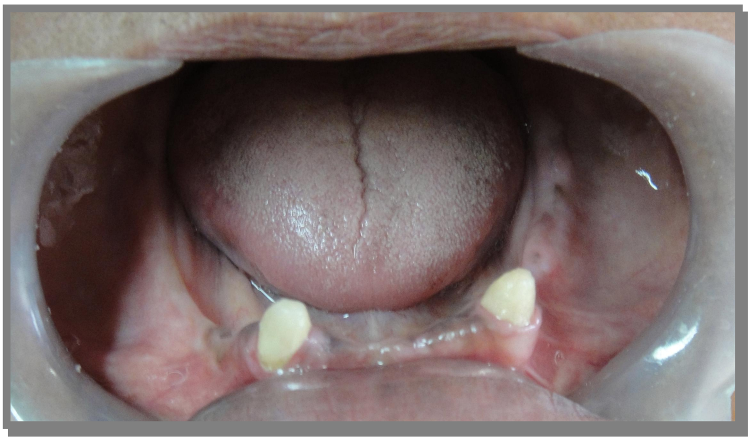




DIAGNOSTIC MOUNTING



POST ENDODONTIC TREATMENT

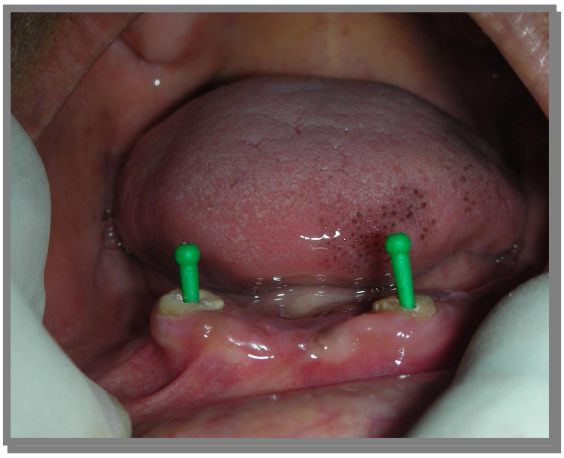


ABUTMENT PREPARATION FOR BALL-CAP ATTACHMENT

GATES GLIDDEN DRILL

PEESO REAMER

IMPRESSION POSTS IN POST SPACE PREPARED

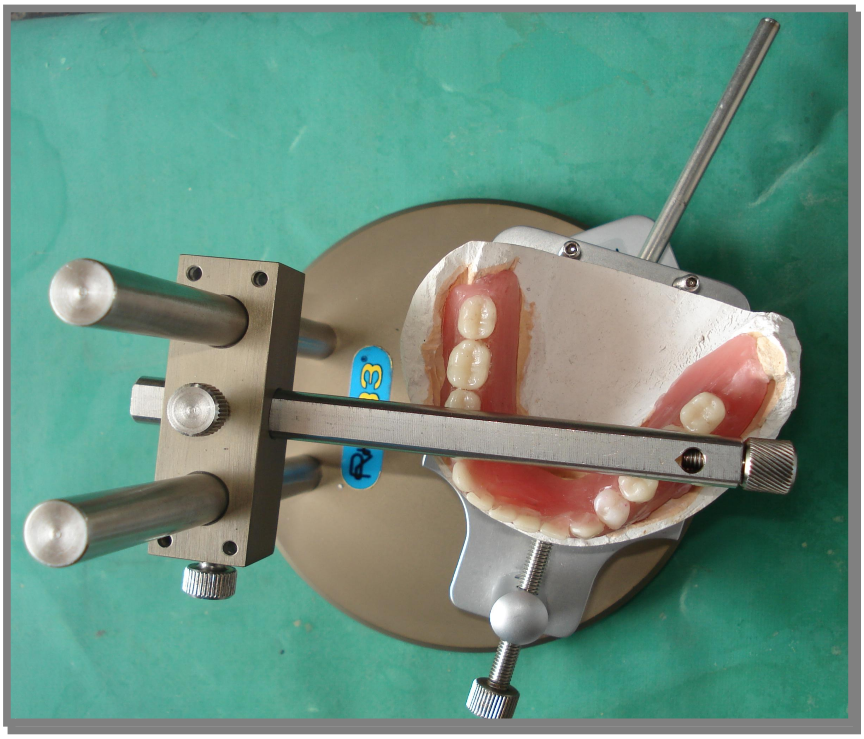


SECONDARY IMPRESSION WITH IMPRESSION POSTS

MASTER CAST

JAW RELATION & WAX TRY-IN

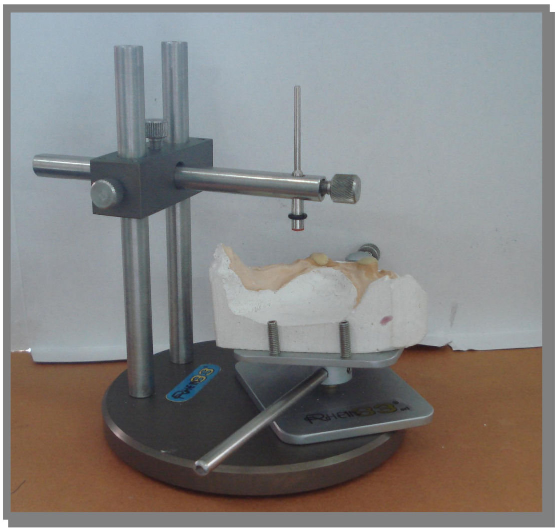
CAST WITH WAX TRY-IN POSITIONED IN PARALLELOMETER



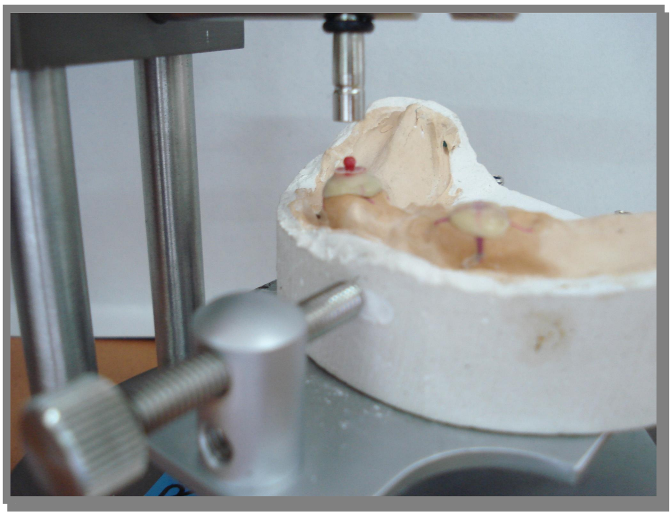
HORIZONTAL ARM PARALLEL TO OCCLUSAL PLANE

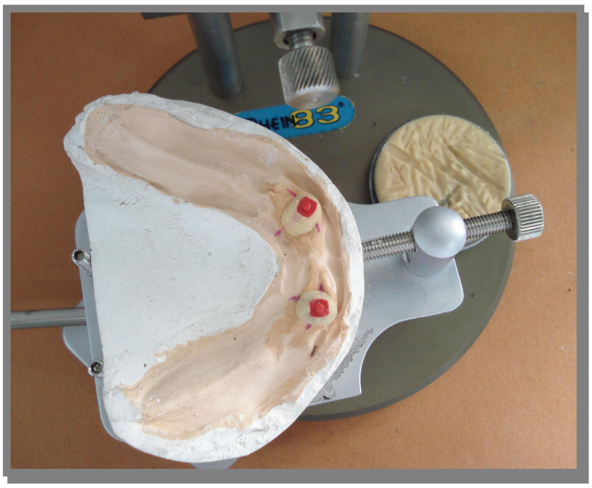
CASTABLE SPHERE AND PARALLELOMETER KEY

CASTABLE SPHERE HELD IN POSITION



CASTABLE SPHERE PLACED OVER RICHMOND CROWN



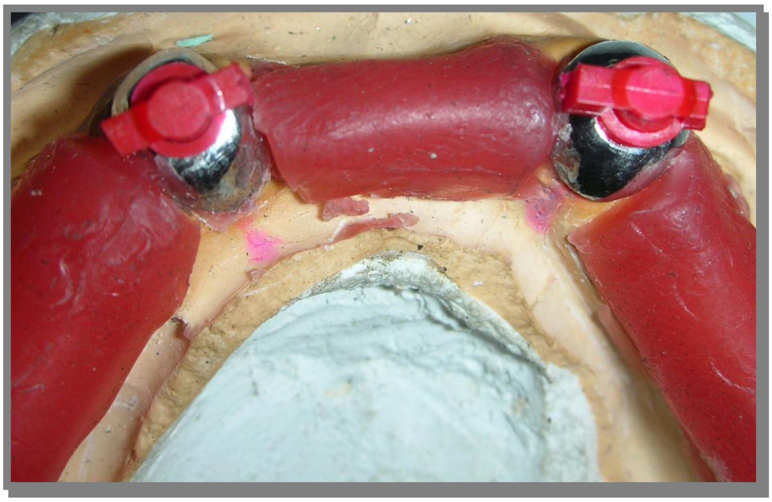


CASTABLE SPHERES PARALLEL TO OCCLUSAL PLANE

CAST RICHMOND CROWNS WITH POSITIONING RING

WAX SPACER

OT BOX (CASTABLE BOX)



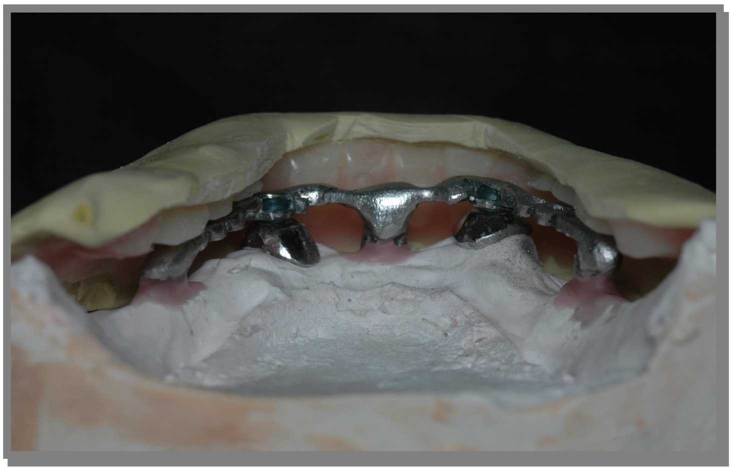
CASTABLE CONNECTOR

FRAMEWORK LUTED WITH PATTERN RESIN

SPRUING

CAST FRAMEWORK

PUTTY INDEX WITH TEETH AND REINFORCEMENT FRAMEWORK



WAX ADDED

FINAL WAX-UP

DEWAXING

FINAL PROSTHESIS

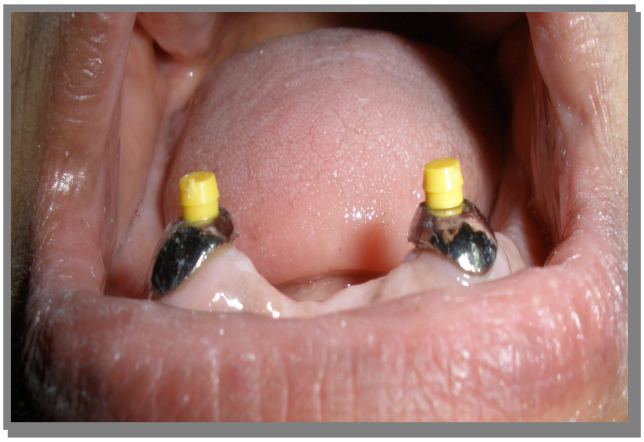
INTAGLIO SURFACE

LUTED RICHMOND CROWNS

RETENTIVE CAPS

POSTOPERATIVE

OVERDENTURE WITHOUT REINFORCEMENT

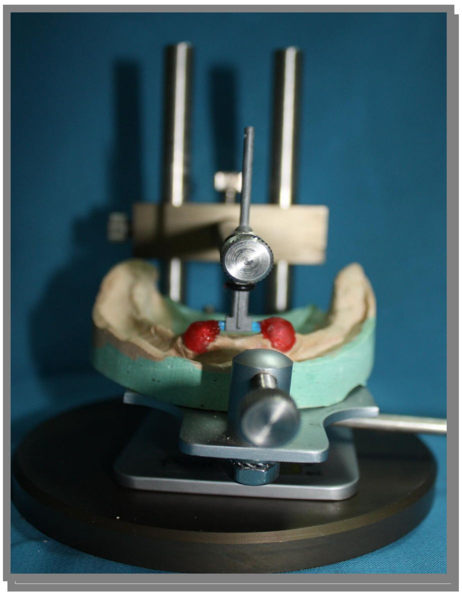


ABUTMENT PREPARATION FOR BAR-CLIP ATTACHMENT

SECONDARY IMPRESSION

MASTER CAST

BAR POSITIONED PARALLEL TO OCCLUSAL PLANE



CAST BAR

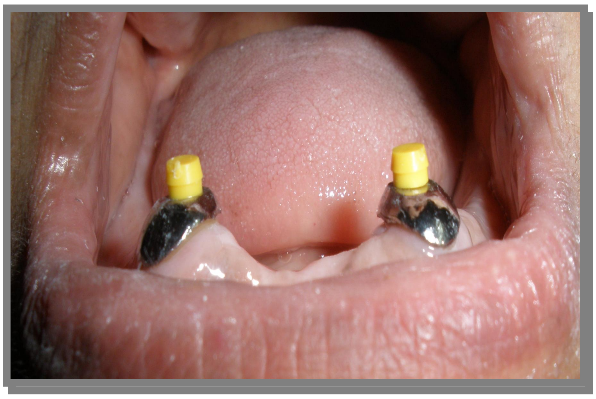
CLIP POSITIONED OVER THE BAR

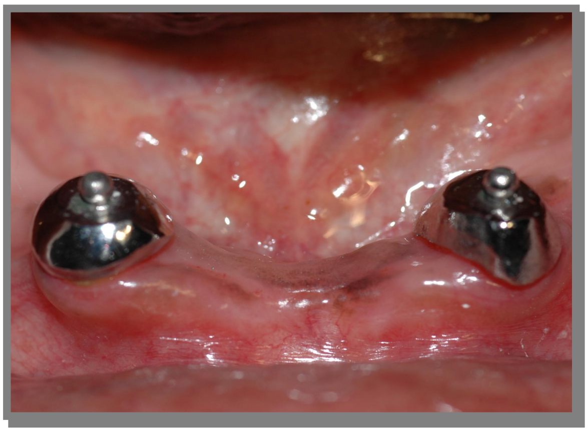
BAR PICKED UP IN DENTURE

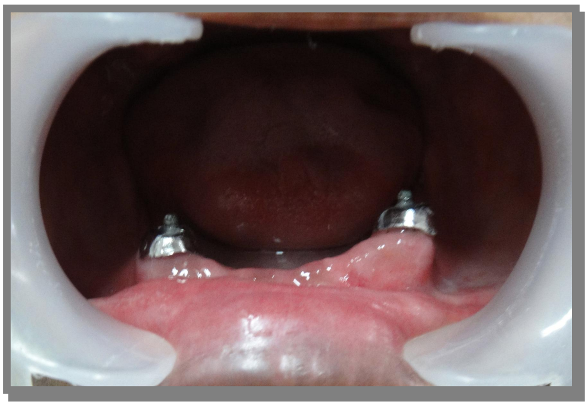
RETENTIVE CLIP IN SITU

FINAL PROSTHESIS

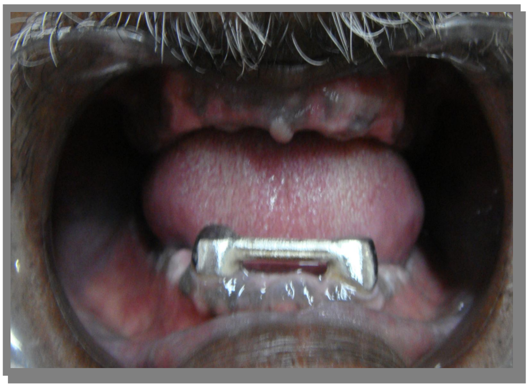
BALL-CAP RETAINED OVERDENTURES







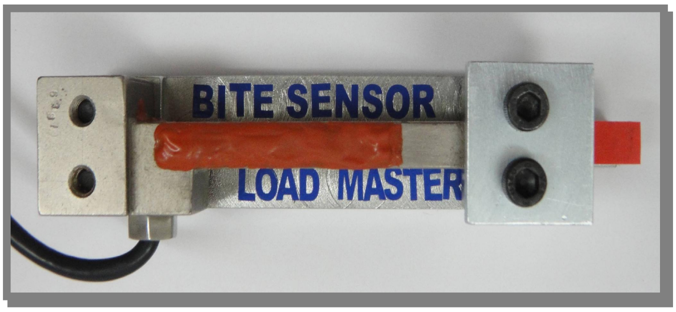
BAR-CLIP RETAINED OVERDENTURES

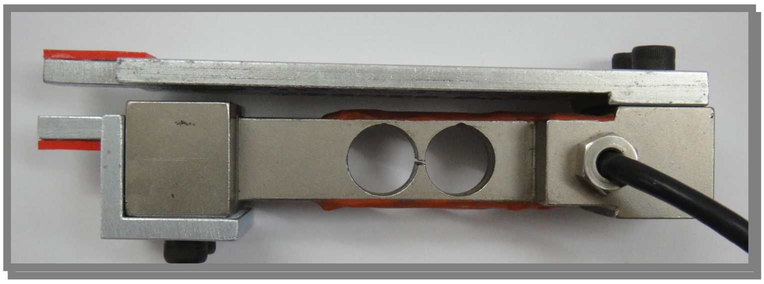




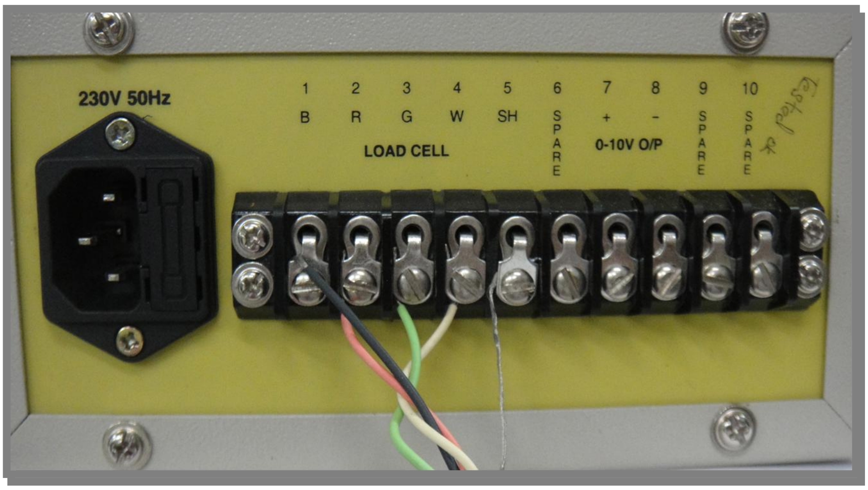



BITE FORCE METER





DIGITAL INDICATOR



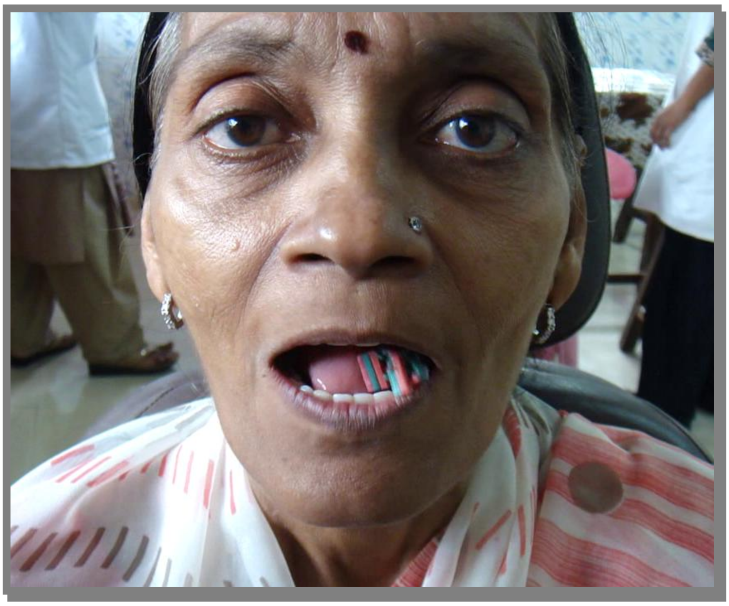
MEASURING BITE FORCE ON RIGHT SIDE

METAL DIE WITH MOULD SPACE

PARAFFIN WAX STICKS

TWO COLOURED PARAFFIN WAX CUBE

WAX CHEWED



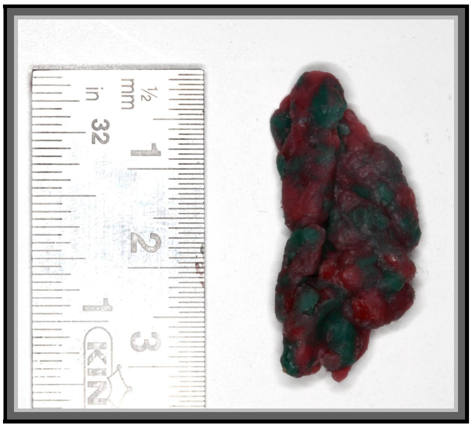
CANON DIGITAL
EOS 5D – 21 MP

MACRO LENS

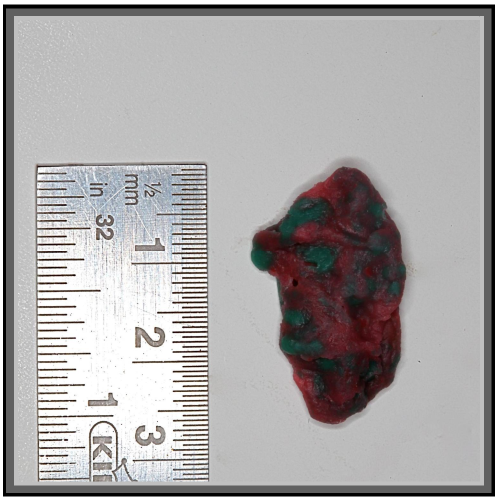
RING FLASH

CLASSIFICATION OF SAMPLES

GOOD



MEDIUM



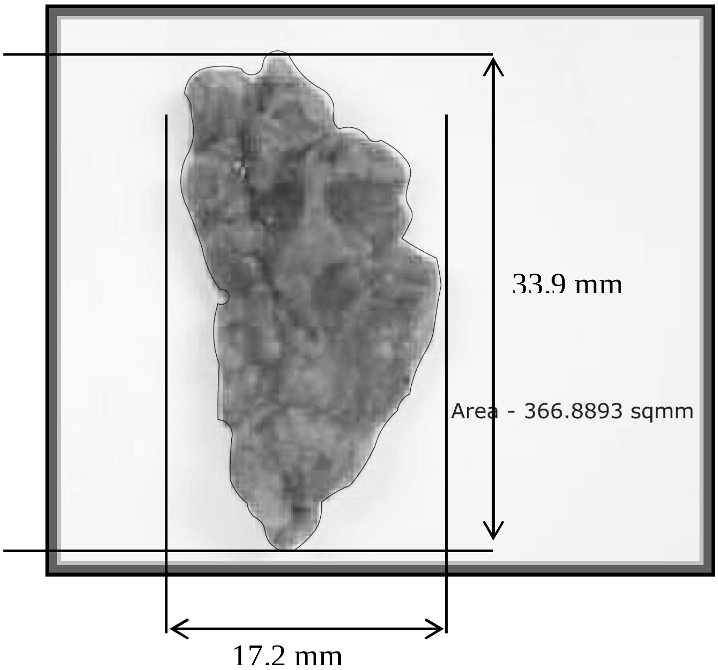
POOR

MONOCHROME IMAGE

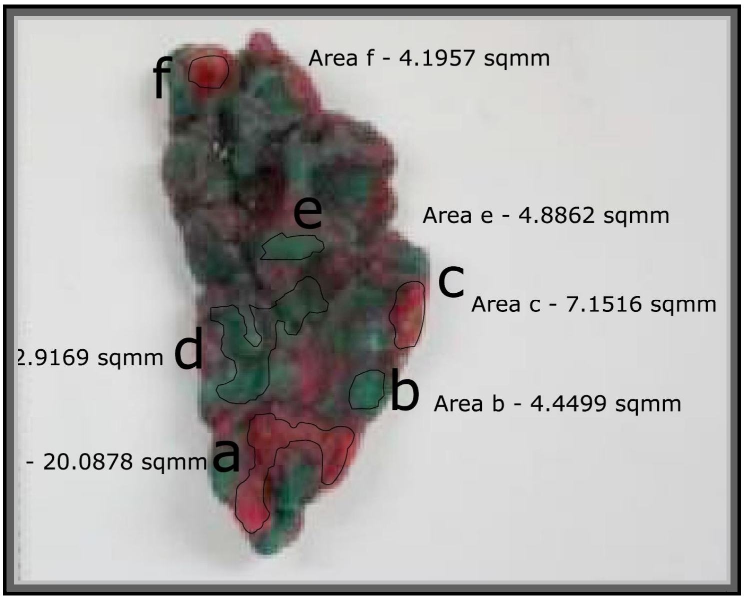
TOTAL AREA

MAXIMUM LENGTH

MAXIMUM BREADTH

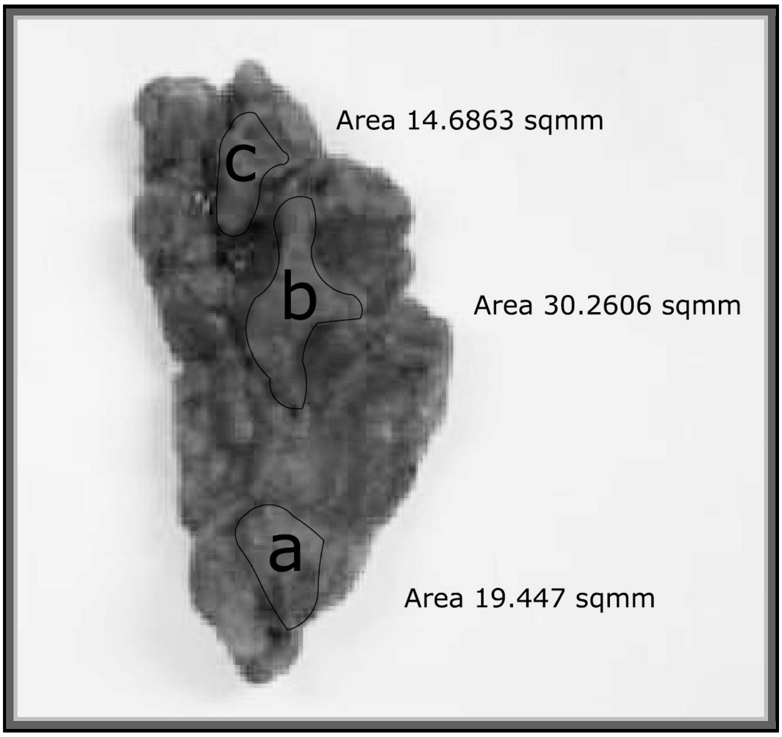


COLOUR IMAGE - RA & GA



3D REPRESENTATION

PROJECTED AREA



RESULTS

RESULTS

This clinical study was performed to compare the maximum bite force and masticatory performance of patients rehabilitated with tooth-supported overdentures retained by two different attachments namely, ball - cap and bar – clip. These patients were compared with conventional complete denture wearers and subjects with natural dentition.

The subjects were divided into four major groups based on the oral condition and the restorative procedure. So a total number of 16 patients were included in the study and each group comprised of 4 patients.

The maximum unilateral bite force and masticatory performance were measured after 1 month of post-insertion period, so that the abutment teeth were actively loaded and also the patients were used to the dentures. The maximum bite force on the right and left side were measured separately and compared. The masticatory performance was assessed from the mixing ability index (MAI), which was a discriminant function. The discriminant function was derived from the discriminant analysis of five variables which were calculated from the measurements obtained using the image analysis of the chewed wax cube.

The mean values and Standard deviation of the maximum bite force on the right and left side were recorded for each group. Similarly the Mean and SD of the mixing ability indices were also calculated.

The basic data of the results obtained in this study are shown in Appendix.

STATISTICAL ANALYSIS OF RESULTS

The overall group comparison was done using One-way ANOVA (Analysis of Variance) followed by intergroup comparison which was done using Tukey HSD

TABLE 4.1 - Comparison of Bite force values on the Right side using One - way ANOVA

GROUP	N	Mean	SD	P value
I	4	290.55	16.87	<0.001**
II	4	61.88	5.32	
III	4	192.15	7.80	
IV	4	203.28	12.17	
Total	16	186.96	84.95	

Note: ** Denotes significance at 1% level

TABLE 4.2 - Comparison of Bite force values on the Left side using One way ANOVA

GROUP	N	Mean	SD	P value
I	4	287.47	13.87	<0.001**
II	4	59.12	4.58	
III	4	190.82	7.17	
IV	4	201.00	8.93	
Total	16	184.61	84.68	

Note: ** Denotes significance at 1% level

TABLE 4.3 - Post Hoc Tests - Multiple Comparisons of bite force values on the right side using Tukey HSD

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	P value
GROUP I	GROUP II	228.67*	8.07681	<0.001**
	GROUP III	98.40*	8.07681	<0.001**
	GROUP IV	87.27*	8.07681	<0.001**
GROUP II	GROUP I	-228.67*	8.07681	<0.001**
	GROUP III	-130.27*	8.07681	<0.001**
	GROUP IV	-141.40*	8.07681	<0.001**
GROUP III	GROUP I	-98.40*	8.07681	<0.001**
	GROUP II	130.27*	8.07681	<0.001**
	GROUP IV	-11.12	8.07681	.535
GROUP IV	GROUP I	-87.27*	8.07681	<0.001**
	GROUP II	141.40*	8.07681	<0.001**
	GROUP III	11.12	8.07681	.535

Note 1: * denotes significance at 5% level

Note 2: ** denotes significance at 1% level

Note 3: No * denotes no statistical significance

<u>TABLE 4.4</u> - Post Hoc Tests - Multiple Comparisons of bite force values on the Left side using Tukey HSD

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.
GROUP I	GROUP II	228.35*	6.56354	<0.001**
	GROUP III	96.65*	6.56354	<0.001**
	GROUP IV	86.47*	6.56354	<0.001**
GROUP II	GROUP I	-228.35*	6.56354	<0.001**
	GROUP III	-131.70*	6.56354	<0.001**
	GROUP IV	-141.87*	6.56354	<0.001**
GROUP III	GROUP I	-96.65*	6.56354	<0.001**
	GROUP II	131.70*	6.56354	<0.001**
	GROUP IV	-10.17	6.56354	.440
GROUP IV	GROUP I	-86.47*	6.56354	<0.001**
	GROUP II	141.87*	6.56354	<0.001**
	GROUP III	10.17	6.56354	.440

Note 1: * denotes significance at 5% level

Note 2: ** denotes significance at 1% level

Note 3: No * denotes no statistical significance

<u>TABLE 4.5</u> - Pair wise comparison of mean bite force values and SD for right and left side of the Groups using Paired sample-t Test

	Right Side		**Left Side**		**P value**
	Mean	**SD**	**Mean**	**SD**	
Group I	290.55	16.87	287.48	13.87	0.460
Group II	61.88	5.32	59.12	4.58	0.049*
Group III	192.15	7.80	190.83	7.18	0.213
Group IV	203.28	12.17	201.00	8.93	0.398

Note: No * denotes no statistical significance

Note: * denotes significant at 5% level

TABLE 4.6 - Comparison of MAI (mixing ability index) using One way ANOVA

	N	Mean	SD	P Value
Group I	4	1.00075	.021422	<0.001**
Group II	4	.27150	.006557	
Group III	4	.70025	.014796	
Group IV	4	.71050	.012477	
Total	16	.67075	.269027	

Note: ** Denotes significance at 1% level

TABLE 4.7 - Post Hoc Tests - Multiple Comparisons of MAI using Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	P Value
Group I	Group II	0.73*	.010467	<0.001**
	Group III	0.31*	.010467	<0.001**
	Group IV	0.29*	.010467	<0.001**
Group II	Group I	-0.72*	.010467	<0.001**
	Group III	-0.43*	.010467	<0.001**
	Group IV	-0.44*	.010467	<0.001**
Group III	Group I	-0.31*	.010467	<0.001**
	Group II	0.43*	.010467	<0.001**
	Group IV	-0.01	.010467	.764
Group IV	Group I	-0.29*	.010467	<0.001**
	Group II	0.44*	.010467	<0.001**
	Group III	0.01	.010467	.764

Note 1: * denotes significance at 5% level

Note 2: ** denotes significance at 1% level

Note 3: No * denotes no statistical significance

INTERPRETATION OF RESULTS

The data obtained is of quantitative in nature, so the statistical analysis of the bite force and Mixing ability indices were analysed by Analysis of Variance (ANOVA), followed by Tukey HSD.

Table 4.1 shows the comparison of mean values of bite force on the right side for all the groups and ANOVA test was used to find out the statistical significance. The mean bite force of group I was 290.5 N, group II was 61.8 N, group III was 192.2 N and group IV was 203.3 N. The P value was <0.001, so statistically significant at 1% level.

Table 4.2 shows the comparison of mean values of bite force on the left side for all the groups and ANOVA test was used to find out the statistical significance. The mean bite force of group I was 287.5 N, group II was 59.12 N, group III was 190.8 N and group IV was 201 N. The P value was <0.001, so statistically significant at 1% level.

Table 4.3 shows the inter-group comparison result for the right side which was done using Tukey HSD test. The P value of group III with group IV was 0.535 and was found to be statistically insignificant. The P value for comparisons between the other groups were <0.001 and therefore statistically significant at 1% level.

Table 4.4 shows the inter-group comparison for the left side which was done using Tukey HSD test. The P value of group III with group IV was 0.440 and was found to be statistically insignificant similar to that of the right side.The

P value for comparisons between the remaining groups were <0.001 and therefore statistically significant at 1% level.

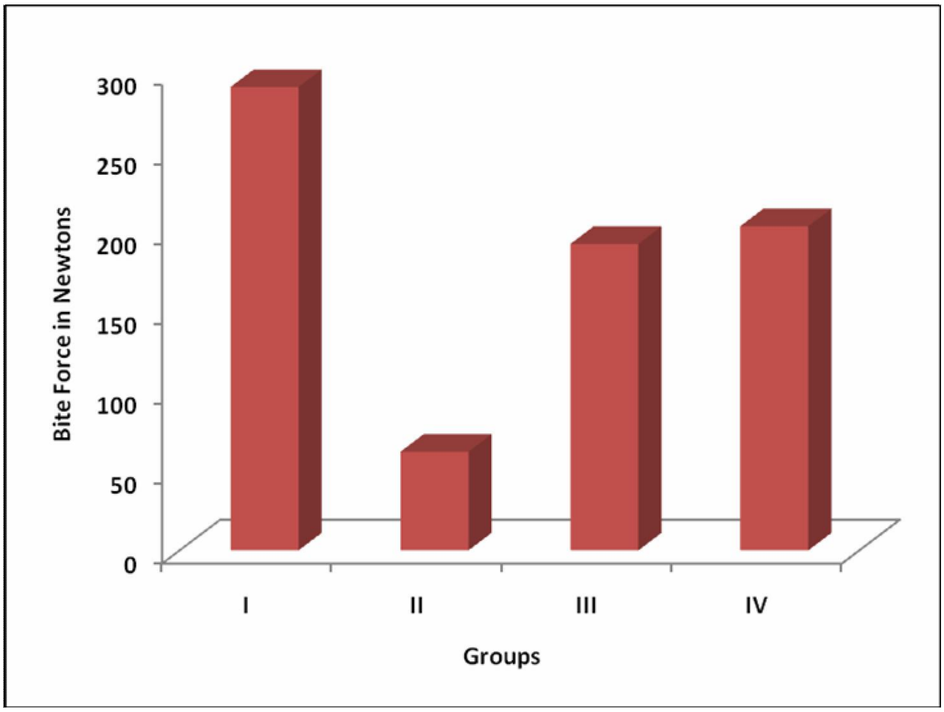
Table 4.5 represents the paired sample comparison of the right and left side by Students Paired t Test. The P value of group I right side with left side was 0.460, for group II – 0.049, for group III, it was 0.213 and group IV right and left side had a P value of 0.398. The P value of group II for the comparison between the right and left side was significant at 5 % level while the comparison amongst the remaining groups were found to be statistically insignificant.

Table 4.6 shows the comparison of mean values of mixing ability indices for all the groups and ANOVA test was used to find out the statistical significance. The mean mixing ability index of group I was 1.00, group II was 0.27, group III was 0.70 and group IV was 0.71. The P value was <0.001, so statistically significant at 1% level. Based on the mixing ability indices, the group I was classified as good, group III and IV as medium and group IV categorized as poor sample group.

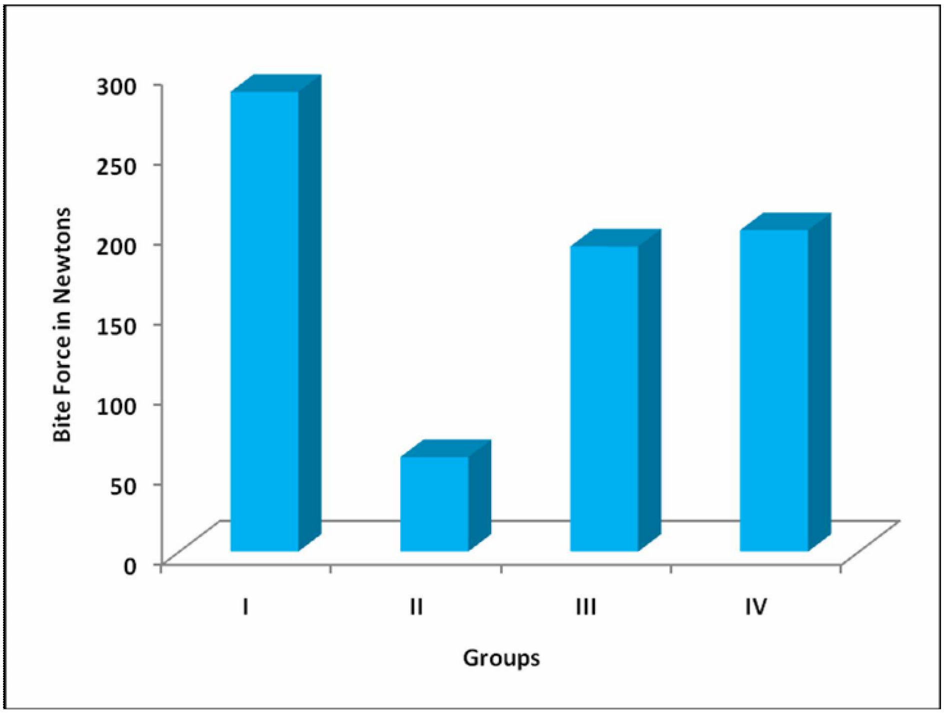
Table 4.7 shows the inter-group comparison of MAI which was done using Tukey HSD test. The P value of group III with group IV was 0.764 and was found to be statistically insignificant similar to bite force values. The P value for comparisons between the remaining groups were <0.001 and therefore statistically significant at 1% level.

BAR DIAGRAMS

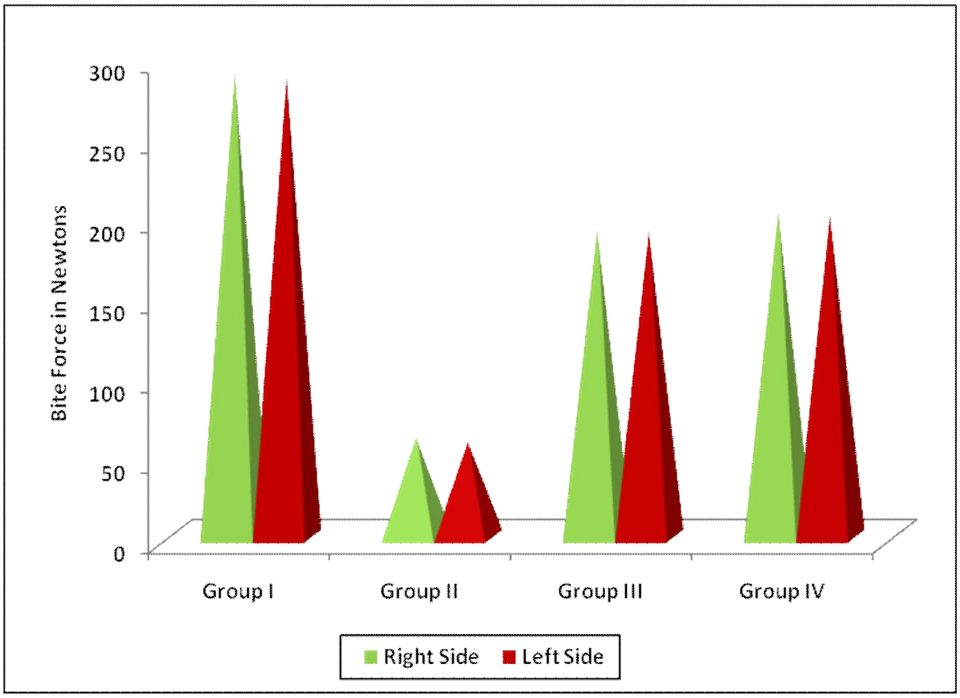
COMPARISON OF BITE FORCE VALUES ON THE RIGHT SIDE USING ONE -WAY



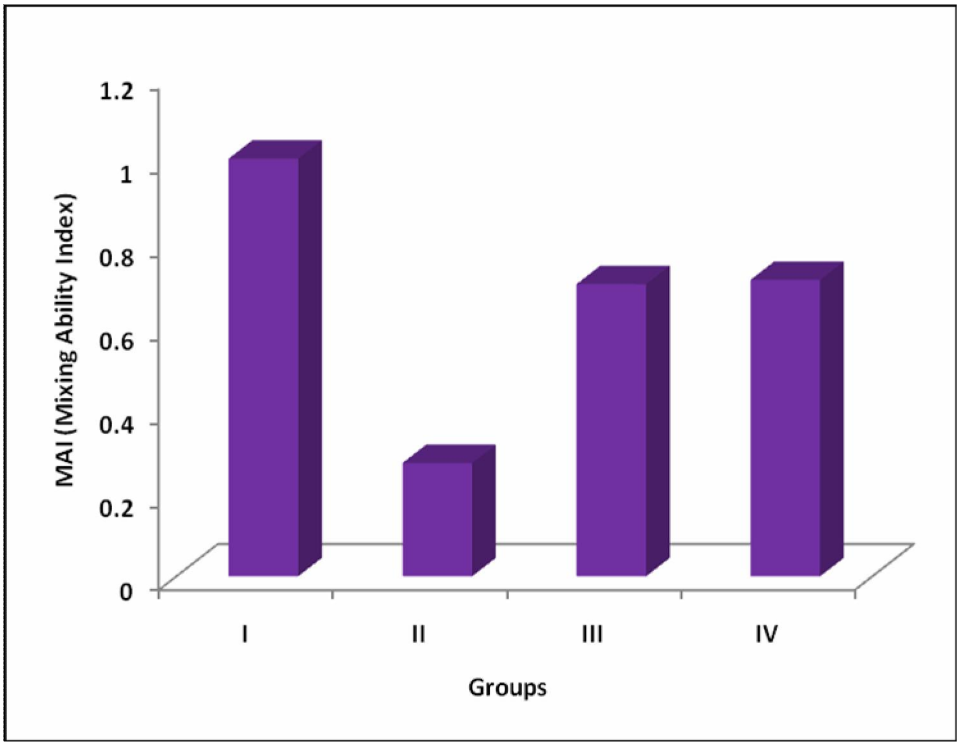
COMPARISON OF BITE FORCE VALUES ON THE LEFT SIDE USING ONE -WAY



COMPARISON OF MEAN BITE FORCE VALUES FOR RIGHT AND LEFT SIDE



COMPARISON OF MAI (MIXING ABILITY INDEX) USING ONE WAY



DISCUSSION

DISCUSSION

The transition from natural teeth to becoming edentulous and wearing dentures is often a traumatic physical and psychological experience for the patient. Residual ridge resorption following tooth extraction is a continuous process resulting in unfavorable jaw anatomy and inadequate support for dentures. The mandibular denture often becomes the focus of patient's concern because of the reduced surface area and the presence of highly mobile organ, the tongue. **Tallgren et al**[66] reported that a complete denture wearer's ability to comminute food during mastication is markedly reduced to 1/4 or 1/7 that of adults with natural dentition depending up on the age, and the type of food intake. In order to compensate with the loss of masticatory efficiency, patients tend to swallow larger food particles instead of prolonging the number of chewing strokes. They also attributed this to their lack of appropriate discriminatory ability since chewing is a selective process.

Redford et al[67] demonstrated that more than 50% of conventional mandibular complete dentures have problems with retention and stability, resulting in more patient dissatisfaction than maxillary dentures. Inadequate retention and stability with conventional complete denture therapy often results in functional deficits and the patient's satisfaction, confidence, and comfort commonly suffer[1].

Pacer[15] compared the discriminatory ability of subjects with conventional complete dentures and overdentures and found that complete denture patients have lower discriminatory threshold below 2000 g level. **Robert M. Morrow**[10] proposed that tooth-supported complete dentures are a valid approach to preventive prosthodontics and indicated when four or less retainable teeth are present in the dental arch.

Different terms were used to refer the tooth – supported overdentures such as "hybrid prosthesis"[68] because they had a fixed as well as a removable component, "biologic stabilizers"[6] since complete denture prostheses gain support from the teeth which are biologic by nature. The overdentures were considered to play a major role in Preventive Prosthodontics because of their potential to retard the residual ridge resorption. **Crum and Rooney**[16] reported a significant reduction in mandibular bone loss after 5 years in patients wearing overdentures as compared with subjects using conventional complete dentures and found an average bone loss of 0.6 mm compared with 5.2 mm respectively. In addition, sensory feedback of the periodontal receptors is maintained and masticatory performance may be enhanced.

Sensory input from the periodontal receptors is one of the major determinants of masticatory function and roots of the teeth offer more discrete discriminatory input than the oral mucosa[47]. **Kay and Abes**[69] concluded that the neuromuscular control of mandibular movements was improved by retaining natural teeth in overdenture patients when compared to complete denture patients. **Rissin et al**[70] compared the chewing efficiency of patients with natural dentition, overdentures and conventional complete dentures and found the masticatory performance of natural dentition to be at 90%, complete denture wearers at 59%, and patients with overdentures at 79%.

Psychologically, preservation of a few teeth may be perceived by the patient as an important factor in maintaining a more positive self-image. Although it is impossible to eliminate all adverse neurological effects, the tooth-supported overdentures help to restore a high degree of tactile discrimination.

So, this study was performed with the aim to give insight into the masticatory ability and the maximum bite force of patients rehabilitated with tooth – supported overdentures and compared with that of the complete dentures.

SELECTION OF ABUTMENT:

Manly et al[46]**, Kawamura and Grossman et al**[9] observed that the sensitivity of natural anterior teeth was hundred times more than that achieved with the complete dentures, since a greater concentration of sensory receptors are present in the anterior part of the mouth. Generally, two to four overdenture abutment teeth, that are widely spaced, are sufficient to provide a broad area of contact between the abutment teeth and denture base and also avoid interproximal gingival impingement. The plaque control can result in complications when a denture base fits closely over the two adjacent teeth. When two teeth are used, they should be located bilaterally in the mandibular anterior region.

Accordingly, mandibular canines were preferably chosen as the abutments for supporting and stabilizing the overdentures since they have a larger surface area for attaching the periodontal fibers and are among the last teeth to be removed from the oral cavity with periodontal disease. **Langer Y & Langer A**[71] showed that the mandibular canines have four times higher survival index than any other tooth. The shape and position of the canine makes them less likely to become victims of tooth decay than the posterior teeth which have a larger interproximal contact area. They are in the corner of the arch, where the posterior segments join the anterior component and act as the keystone of the arch; hence they are in a strategic position for use as abutments[8].

Abutments with minimum of 7 mm alveolar support and mobility less than grade II were selected for this study because the prognosis of the overdenture therapy depends on the periodontal health of the abutment teeth[72]. The pattern of mobility was recorded so that teeth with horizontal and vertical displacement were discarded.

Lang and Loe[C2] considered the acceptable minimal amount of attached gingiva of the unaltered dentition and found that, when less than 1 mm of attached gingiva was present, chronic inflammation was evident, even in the absence of bacterial plaque. In this study, a minimum of 3 mm of attached gingiva was considered as an inclusion criteria because this tissue acts as a barrier against the insults to which the gingival cuff is submitted. When doubt exists about the adequacy of attached gingiva present, the region should be augmented surgically or followed closely at frequent recall visits

Radiographs such as OPG and intra oral periapical were taken to assess the prognosis of the abutment teeth since radiographic C/R ratio was considered as an indicator of osseous support. Panoramic radiographs were taken to assess the maxillary sinuses, temporomandibular joint and to rule out any pathologic entities like impactions, cysts, retained roots, foreign body masses.

Takehisa Tanaka et al[25] reported that stresses around the cortical bone increased as the crown – root ratio increased and the maximum concentration of stresses was observed near the cervical region of teeth with crown restorations than those without any restorations, due to the elimination of cantilever effect.

In this study, teeth with more than or equal to 1:1 ratio were selected, as they can still provide support for the prosthesis by reduction of the abutment tooth into a dome shape and extending only a few millimeters above the free gingival margin, thereby minimizing the harmful lateral forces. **Niels brill**[68] showed that if the stresses exerted on a compromised tooth are within the limits of tolerance, the periodontium accommodates itself to the challenge by a proliferative response and thus they are found to be lodged firmly in their sockets. The overdenture abutment tooth being coronally reduced facilitates an axial resolution of occlusal forces, resulting in deposition of bundle bone, thereby minimizing the lateral forces and tooth mobility as well.

In the present study, the tooth preparation for the abutments varied based on the type of attachment being used, in order to improve the crown-root ratio and thereby allow space for both attachment and overlying denture tooth. Since, the ball and cap attachments were independent, the coping height was reduced comparatively more than that for the bar and clip attachment, so as to avoid the lateral forces and excessive stresses on the abutment teeth[73]. For fabricating Richmond crown, the abutments were reduced up to 1-2 mm above the level of gingival crevice in order to avoid any mechanical injury to the periodontal fibers, whereas for the bar and clip attachment, it was reduced to a dome shape of about 3mm above the free gingival margin.

Endodontic treatment was done for all the overdenture abutment teeth so as to retain the natural tooth root in its alveolar bony environment for retention, support, and stability of the overdenture, to preserve and maintain the height of the residual ridge and create a favorable crown-to-root ratio[74]. **Adler, Bunting**[5] studied the sensory input capabilities of vital and non-vital teeth and found no difference in their stimulation. Since the canines are single-rooted teeth, endodontic treatment was amenable for all of them.

Merrill C. Mensor[65] stated that the length of the cast dowel should be atleast 8 mm or else the coping would separate from the tooth when the attachment functions. In the present study, since the abutment teeth were periodontally compromised, the criterion of minimum of 8 mm was not satisfied, so the apical 1/3rd or 5mm of gutta percha material, whichever was greater, was left intact while preparing the post space. The post space preparation was done using the Gates Glidden drill and peeso reamer instead of the Mooser bur supplied by the manufacturer for maintaining the resistance form of the preparation.

Russell H. Augsburger[75] showed that the cuspid mobility reduced by 83% when cross-arch splinting and crown length reduction was done. The crown-root ratio of mandibular cuspid is 5:8 and the abutment teeth were prepared to a height of 4 to 5 mm so that the bar may be placed as close to the residual alveolar ridge as possible thereby strengthening the abutment teeth. The bar was placed parallel to the occlusal plane which was established earlier so that the space for denture base material is provided uniformly and also the path of insertion was defined.

Dolder[28] proposed that the bar should be positioned perpendicularly to a line bisecting the angle between the posterior ridges because an oblique position of the bar impairs correct function of the joint.

SELECTION OF ATTACHMENTS :

Root-supported overdentures gain their retention and stability from the use of attachments which are simple connectors consisting of two components. Attachments are either resilient or rigid with one part fixed to the root of the abutment tooth and the other part to the intaglio surface of the acrylic overdenture. A resilient attachment has vertical, lateral, and hinging movements which allow the prosthesis to move over the abutment and redirects the load over the posterior mucosa, thereby reducing the stress on the abutment tooth[76]. In order to divert the occlusal forces away from the abutment teeth and allow for more ridge support, resilient attachments were used in this study, for the design of tooth-supported overdentures.

For diagnosis and treatment planning, an accurate spatial determination between the maxillary and mandibular dental arches is critical. The diagnostic casts were mounted in the centric relation so that the interarch distance dimension was clearly visualized and accurately measured prior to selection of attachments, also to gain information about the jaw relationships, tissue undercuts and teeth alignment. In the present study, two attachments were used namely, the ball and cap, bar and clip attachment based upon the interarch distance, periodontal status and interabutment axis. Based on the available inter arch space, attachments were selected as normal size for adequate space and micro size for lesser denture space.

Brett Cohen et al[37] pointed out that bars encroach more on the tongue space and reduce the functional deformation of the mandible whereas the use of stud attachment requires less space. **Gotfredsen & Holm**[77] suggested that single attachments make for easier hygiene maintenance and fewer technical complications, also used when the abutments are located very distally or in a diagonal arrangement. In 1 case, ball - cap attachment was used because of the narrow lower arch and diagonally placed abutment teeth.

Assunac et al[78]**, Bergendal T**[79]**, Naert et al**[80]**, Mericske-Stern et al**[81,82] **and Heckmann et al**[83] verified that for rigid attachments (bar-clip attachment), better stress distribution was observed on the implant, its prosthetic components and the edentulous ridge compared to poor stress distribution of stud attachments, suggesting that the splinted implants promoted better horizontal stability, reducing the stress development in the supporting tissue whereas the greater resiliency of the O-ring system in stud attachment allowed a higher amplitude of movement of the prosthesis. Therefore, these studies gave a pertinent suggestion that an overdenture retained with bar attachment can be clinically assumed as capable of optimized stress distribution, minimizing bone resorption rate.

On the contrary, **Robert Kenney and Mark W. Richards**[84] demonstrated that the ball/O-ring attachments transferred less stress to implants than the bar-clip attachments when the photoelastic model was subjected to a posterior vertical load. However, these studies may not be applicable to tooth – supported overdentures because the natural tooth adapts to its loading situation through the periodontium, but an appropriate degree of functional implant loading is beneficial for bone remodeling around an implant. For natural tooth overdentures, **Thayer and Caputo**[36] reported that the Dolder bar created less stress to the retained roots and shared the occlusal load across the arch.

For the cases in this study, the bar - clip attachments were used on those teeth that were periodontally weak and also with poor ridge support, since they have a splinting effect and also limit the prosthesis movement. The castable bar had two versions, rigid and resilient based on the configuration of the superior surface. All the bar-clip attachment retained overdentures in this study, used the rigid version (Version A) for better splinting effect. In 3 out of 4 cases, the abutment teeth had grade II mobility and crown-root ratio equal to 1:1, in addition to poor posterior alveolar ridge, which were selected for bar attachment to provide cross-arch stabilization. Similarly, ball and cap attachments were chosen for 3 cases, in which the abutment teeth had good periodontal support but crown – ratio less than 1 and posterior ridge forms were well formed.

In this study, the amount of retentive forces that were necessary to satisfy the patient was compromised, as it must be high enough to prevent displacement of the denture, but at the same time, the forces must not exceed to have a destructive effect on the periodontal tissues which support the abutment teeth, during removal of the denture. The retentive caps used in this study are available with varying degrees of retention as soft, medium and rigid. Most of the elastic caps used for this study were of medium retention for easy removal of the prosthesis by the patient and also to protect the compromised periodontal health of the abutment teeth[85].

Proper attachment selection should be done in order to minimize the torque on abutment teeth and direct the forces along the long axis of teeth which is critical in planning long-term prosthetic success. **Abdullah S. Alsiyabi et al**[86] proposed that the selection of implant abutments and prosthetic attachments should be made during diagnosis and treatment planning and a surgical guide fabricated from a diagnostic wax-up or provisional denture set-up should be used for proper placement of the attachments.

In the present study, the jaw relation recording and wax try – in procedures were done for all the cases, prior to attachment fabrication so as to aid in determination of their size and position. Orientation of the ball and the bar components should be parallel to the occlusal plane of the denture, for easy insertion and removal of the prosthesis. Parallelometer is an instrument which helps to orient the attachments parallel to one another. In this study parallelometer was used for all the cases to orient the attachments, so that the patients were able to handle the prosthesis with ease.

The casting was done using cobalt chrome alloy because of its higher hardness which helped to prevent wearing out of the precise surfaces of ball and bar attachments. Instead of sand blasting, glass blasting was done for the ball and bar attachments because routine sand blasting might abrade the precise contour of the matrix part. **Ricardo T. Abreu et al**[87] evaluated the effects of different bar materials (gold alloy, silver-palladium alloy, commercially pure titanium, cobalt-chromium alloy) on stress distribution in a bar retained overdenture and concluded that the stress levels increased with increase in the elastic modulus of the bar material.

Gonda and Dong[88] investigated the effect of metal reinforcement on overdenture strain around copings and at the midline and the greatest strain was observed on the overdenture without reinforcement. So, they suggested that reinforcement of the denture base along with the top of the coping would be effective in reducing overdenture strain. For fabricating an overdenture with metal reinforcement, a minimum of 25- 30 mm of interarch distance was required which was available in 2 cases, in which ball-cap retained overdentures with metal reinforcement were done. In the remaining cases, the interarch distance was 20 –

25 mm, for which high impact denture base resin was used for processing the attachment retained overdentures without metal reinforcement.

EVALUATION OF BITE FORCE :

Okeson[89] assumed that "ideal" occlusion of the teeth usually specifies even, simultaneous, and bilateral tooth contacts in the intercuspal position that provide a balanced distribution of occlusal force. Maximum voluntary bite force is an important variable for assessing the functional state of the masticatory system in relation with occlusal factors, dentition, dental prostheses, implant treatment, orthognathic surgery, oral surgery, temporomandibular disorders and neuromuscular disease. **Ralph WJ**[90] suggested that a bite force measurement device can be of adjunctive value in assessing the performance of dentures

Different types of measuring devices were used to evaluate the bite force such as piezoelectric elements or miniature strain gauges which can be mounted into a bite fork[91,49], into transducers of various vertical heights[81,92], into the mandibular denture[57], into a duplicated maxillary denture[93], at the denture-mucosa interface of the maxillary denture[81], or even into implant abutments[2].

The inter-subject variability of maximum occlusal force results from a complex interaction of many factors such as sex, age, body mass index, presence of temporomandibular disorders, craniofacial morphology, dental occlusal status, periodontal sensitivity and psychological factors but are consistent in certain range within each subject[C3, C4].

Hatch et al[59] reported that age factor might directly affect the biting force and so for this study, patients of age range between 45 and 60 years old were selected to avoid variation in masticatory performance and bite force.

Electrical strain gauges are considered as one of the most common methods of measurements in experimental stress analysis because of their relative simple installation and adequate response to both rapidly fluctuating and static strain with easily recording output signals.

In this study, a strain gauge was firmly stuck onto a dual beam transducer which in turn was connected to a strain meter. The strain gauges were covered by epoxy resin so as to be isolated from saliva and blood to prevent short circuits and also to measure strain correctly[94]. This bite force measurement device had two beams which were compressed when occlusal load was applied, similar in design and mechanism to those used in the other studies[82,92]. This transducer design was used in the study because it was easy to handle, cost effective and more precise with the fluctuating strain encountered in the oral cavity.

The patient was seated in an upright position, eyes forward and occlusal surface of upper denture parallel to the floor as mentioned by Tingey et al[C6] since the position of head and body of patients would affect the measurement of bite force.

The dual beam transducer was 15mm thick so that the subject's bite was opened 20- 28 mm between incisors. According to **Manns et al**[95] and **Paphangkorakit and Osborn**[96] this falls into the optimum range to produce maximum force.

Pivolva et al[97] showed that second bicuspid carried the heaviest load and provided best lever balance to stabilize the denture base during functioning without much pressure on temporomandibular joint so the dual beam strain gauge transducer was placed in the second premolar and first molar region. **Korioth and Hannam**[98] studied differential tooth loading during tooth-clenching with a three-dimensional finite element (FE) model and higher bite forces were evident at the most posterior tooth locations, consistent with the lever theory. This non-uniform grading of bite force with the highest values on the molar teeth reflected the complex bending of the mandible, its form and elastic properties.

The beams were made flat and smooth which positioned the strain gauge as parallel as possible to the occlusal plane, spreading the load vertically and minimizing measurement error during testing[C6].

Bakke M. et al[99] recognized the importance of denture stability while measuring the bite force and used bilateral force transducers to stabilize the dentures during biting tests. However, a bilateral force transducer does not reflect the normal function in denture patients since they are not able to symmetrically distribute their occlusal forces during chewing and biting. In this study too, a mouth prop was used on the contralateral side to prevent the tipping of the maxillary denture while recording the bite force.

An interval of at least a minute was permitted to elapse between each experiments as it was previously proved necessary to provide time for strain gauge meter to return to zero balance after loading[100].

The results of this study were evident that the bite force can be higher in one side of the mouth which has been proved in earlier studies, though it was not statistically significant except for the conventional complete denture subjects[101].

The results obtained in this study showed that the average bite force value of the conventional complete denture patients was only 21 % of that of subjects with natural dentition. This decrease in bite force is quite understandable and it may be attributed to less exertion of force by the edentulous jaws as compared to dentate patients. Past studies have demonstrated that the complete-denture wearers are often regarded as oral invalids, since their bite force is reduced to only 20 to 50% of that of dentate subjects. (**Carlsson**[93]**, Michael et al.**[42]**, Slagter et al.**[92]**,**).

In this clinical study, the tooth – supported overdenture groups showed a statistically significant increase in the bite force values when compared to that of the conventional complete dentures, but considerably lesser than the natural-dentition group. The improved retention and support of the mandibular denture by the retained abutment teeth allowed the subjects to exert much better forces.

The tooth (root) supported overdentures with attachments of both ball-cap and bar-clip offer better stability during function than that of overdentures made without attachments. So, the incorporation of attachments improves the stability appreciably and it has been proved in the previous studies [58]. **Venita Sposetti et al.**[51] studied the effect of attachment retained overdentures on oral function, before and after placement of attachments. The bite force and electromyographic activity during mastication increased considerably after placement of attachments.

With this study design, the difference between the maximum bite force values of the two tooth – supported overdenture groups were not statistically significant, as the mean bite force value of bar-clip retained overdenture group was 203 N and that of ball-cap retained overdenture group was 192 N.

This observation acknowledged the findings of **Van Kampen et al**.[2], who demonstrated that the degree of implant support or the type of attachment does not seem to evoke major differences in maximum bite force. In their study, the maximum bite force with attachments was only two-thirds of the value of 487 N reported for dentate subjects. This limitation of the maximum bite force was attributed to the maxillary denture, which has no attachments and therefore less retention and stability. When the subjects clenched, pain in the maxilla may occur because of dislodging of the maxillary denture.

The patients rehabilitated with tooth-supported overdentures, in the present study, were satisfied with their prostheses, irrespective of the attachment and the processing method used. **Cune M, Van Kampen F**[102] also conducted a study to determine the relationship between patient preference and maximum bite force with three different types of attachments for implant retained overdentures in 18 edentulous patients. The mandibular denture was initially without any attachment, but later fitted with one of the attachment types after 3 months and the attachments were changed 3 months thereafter, in random order. Patients strongly preferred bar-clip (10/18 subjects) and ball-socket attachments (7/18 subjects) over magnet attachments (1/18 subjects). But maximum bite force was not correlated to VAS score and it was concluded that patients with higher maximum bite forces were not necessarily more satisfied.

The observation of results of this study revealed that the overdenture with attachments irrespective of the type performed much better than conventional complete dentures. Better application of bite force may be attributed to more firmly held up position in the edentulous arch and fairly good amount of proprioceptive feed-back mechanism.

MASTICATORY PERFORMANCE

One of the treatment goals in restoration of natural teeth or the replacement of missing teeth is to achieve an acceptable masticatory function. **Carlsson**[93] defined masticatory ability as an individual's own assessment of masticatory function, whereas masticatory efficiency is defined as the capacity to reduce food during mastication. **Bates et al**.[103] defined masticatory performance as the particle size distribution of food when chewed for a given number of strokes.

Since this study focused on the number of chewing strokes while assessing the masticatory function, it was proposed that masticatory performance was being evaluated.

Masticatory performance is affected by several factors like the status of posterior teeth, bite force, malocclusions, and occlusal contact area, of which the status of posterior teeth and bite force are two key factors[59]. Different studies have shown direct relationship between chewing efficiency and maximum bite force and nearly half of the variation in chewing efficiency can be explained by bite force alone. Thus, one of the objectives of this study was to correlate the maximum bite force and masticatory performance in subjects with complete dentures, tooth-supported overdentures and natural dentition.

Most of the earlier studies, since 1924, have measured the masticatory efficiency by collecting the chewed food particles and making them pass through sieves of various mesh sizes. Since, the particle size distribution was not uniform; **Edlund and Lamm**[104] used the proportion by weight of food trapped by coarse, medium and fine meshes, to derive an index of chewing efficiency for the individuals. **Lucas**[105] further simplified the assessment by determining the median sieve size (S50) that would retain 50% by volume of the particles.

Real foods, including carrots[58], peanuts[46] and almonds[106] have been used to measure masticatory performance. But it was difficult to change hardness with real foods. Few other studies used artificial test foods such as standardized sizes of formalin-hardened gelatin[50], round tablets of silicone impression materials (e.g. Optocal TM) with different hardness[92]. **Yamamoto and Yoshida et al.**[107]**,** experimented with gummy jelly, whose hardness can be differed with the same shape and taste.

Artificial test foods may be preferred to natural foods for measuring masticatory performance and efficiency because of a better reproducibility of their physical properties. The texture of natural foods such as carrots, peanuts and almonds cannot be standardized while the use of artificial test foods would give a more standard masticatory performance. **Heath MR**[49] proposed the use of chewing gum and measuring the percentage of sweeteners chewed out during a defined number of chewing strokes. This test avoided the discomfort of particles under the dentures which occurred in tests based on fracture of nuts.

Computer-assisted image processing can also be used to analyze the size of masticated test particles with many advantages such as simplicity, speed, accuracy, reproducibility, and hygiene. Compared with sieving, this method was practical for measuring a large number of samples too[50].

J Huggare and Skindhoj[106] developed a new chewing material consisting of equal amounts of barium sulphate and carnauba wax to which colour and binder were added. The masticatory performance was assessed using spectrophotometric analysis of the standard colouring agent and the supernatant fluid of the pulverized test material. Although the sieve test was established as an objective method for dentate patients, it was reported that the lower the modulus of elasticity of test foods, the higher the masticatory performances[108].

Also, **Garrett et al**[109] concluded that measurement of masticatory performance for the complete denture wearers by the sieve test may not be enough to evaluate the masticatory function in the clinic comprehensively. So, colour changing chewing gums were considered to be a reliable method to evaluate the dentures by using an appropriate color scale. The accuracy of visual evaluation of color change by clinicians was similar to that of the image processing techniques[61].

With these visually objective tests, the denture wearers themselves may be able to easily evaluate their dentures and understand the time and need for new denture fabrication. Quality assessment of the prosthesis instantly at chair side without using special equipments, was possible both by the dentists and the patients. But, these methods used ordinary variables from one to five for the different grades of mastication. It was difficult to assess the masticatory performance in detail.

Sato et al[110] proposed an objective method for evaluating masticatory performance which is feasible in clinical use. This study design also used a similar method to assess the masticatory performance. A test food was made from two-coloured paraffin wax and the degree of colour mixing and the shape of the chewed test food were measured to express the value of mixing ability.

The paraffin cube was a new artificial test food that had a texture of chewing gum without any taste as well as smell. None of the subjects of this study, complained any discomforts of chewing it. As **Hirano K et al**[108] stated, the nature of paraffin wax did not influence the mastication, owing to its low modulus of elasticity. Since, the colour pattern and the stacking arrangement of the wax cube were standardized; the test cube had no polarity. Red and Green colours were added because they were found to be the most suitable pair for image analysis and provided the best precision. The wax cubes were made by stacking the red and green coloured wax sticks alternatively, which produced better colour distribution as well as reinforcement of the wax cube. The temperature of the paraffin cube was maintained at 37 ^{0}C and also liquid paraffin was added, so the cubes were not hard and brittle, in early stages of mastication.

This study evaluated the masticatory performance by measuring the degree of colour mixing and the shape of the chewed sample. These variables were used to classify the samples as good or poor based on their mixing ability indices. The mixing ability index was a one-dimensional value to assess the increase in surface area of the cubes which is an important factor in masticatory function. The increase in surface area of food would help the digestive enzymes to penetrate better and create efficient nutrition uptake.

The subjects were asked to chew the artificial test food for 20 strokes based on the need to standardize the measurable masticatory efficiency by all subjects but short enough to discriminate between those with an excellent masticatory efficiency[49].

Fontijn-Tekamp FA et al[58] reported that bite force has a large influence on the masticatory performance and correlation coefficients up to 0.8 have been reported. Thus, the bite force explains over 60% of the variance in masticatory performance.

This study also showed that the bar-clip and ball-cap retained overdenture patients were classified as medium group samples in contrast to the conventional complete denture patients, who were categorized as poor group. The mean difference in the masticatory ability indices between the bar-clip and ball-cap retained overdentures was not statistically significant similar to that of the bite force values.

To test the hypothesis that better retention and stability of the denture improve masticatory function, **van Kampen et al**[2] designed a within-subject cross-over clinical trial to study the effects of 3 types of attachments on mandibular implant retained overdentures. They demonstrated that maximum bite force doubled after implant treatment with the 3 designs, while no significant differences occurred among the 3 attachment types. Subsequently, they observed small differences in masticatory function when comparing the 3 attachments.

There was slightly better masticatory performance with the ball and the bar-clip than with magnet attachments.

In this study, it was noticed that there were no statistically significant differences found in the maximum bite force as well as the masticatory performance between the bar-clip and ball-cap attachment retained tooth-supported overdentures, so the null hypotheses was disproved. Furthermore studies which include more types of overdentures are very much needed to establish the better bite force and masticatory efficiency of patients rehabilitated with overdentures.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The extraction of the last remaining teeth and the replacement with complete dentures has many consequences as the patient has to adapt to a new situation with respect to teeth, chewing, swallowing and accept edentulousness, which may lead to psychological problems and social isolation. Treatment with tooth-supported overdentures offers an alternative to conventional complete dentures to increase the comfort of the patients by providing a more stable reconstruction. The use of attachments and adherence to the basic principles of complete denture design can improve both retention and stability of overdentures.

The present study was performed to compare the maximum bite force and masticatory performance of patients rehabilitated with ball-cap and bar-clip attachment retained tooth – supported overdentures with conventional complete denture wearers, by keeping the natural dentate subjects as control group.

The subjects of study were categorized into four groups based on their oral condition and the restorative procedure. So, a total of 16 subjects were included in the study, each group comprising of four subjects.

The restorative procedures were completed and the patients were subjected to the evaluation of bite force and masticatory performance tests. The results obtained were statistically analysed.

Within the limitations of the present study and from the results of the study, the following conclusions were drawn:

1. The mean bite force, on both right and left sides, of the patients rehabilitated with tooth –supported overdentures was found to be significantly ($P < 0.001$) higher than that of patients restored with conventional complete dentures, irrespective of the attachment design.
2. The mean difference of bite force of patients treated with ball-cap attachment and bar-clip attachment retained tooth-supported overdentures was not statistically significant on both the right (P value – 0.535) and left (P value – 0.440) sides.
3. The maximum bite force of subjects with natural dentition (control group) was significantly ($P < 0.001$) higher than all the other groups, on both the right and left sides.
4. The mean bite force of conventional complete denture wearers on the right side was significantly higher than that on the left side (P value < 0.005)
5. The masticatory performance of subjects restored with tooth –supported overdentures was significantly higher than that of the patients with conventional completed dentures, but lesser than for the natural dentate subjects, for both the attachment systems.
6. The mean difference of mixing ability indices of patients treated with ball-cap attachment and bar-clip attachment retained tooth-supported overdentures was not statistically significant (P value – 0.764)

The results of this clinical study revealed that the bite force and masticatory performance of both the attachment retained tooth-supported overdentures may not be as good as natural dentate subjects but comparatively better than the conventional complete denture wearers due to the presence of strategically retained mandibular teeth. The use of attachments would improve the retention and stability of the overdentures despite the periodontally compromised teeth. Most of the studies considered that quantifying the maximum bite force and masticatory performance would assess the effect of dental treatment on oral function. Although, the tooth-supported overdentures did not regain the oral function similar to that of natural dentition, they established a more definite prognosis for the patient compared to a completely edentulous state.

ANNEXURE

DEPARTMENT OF PROSTHODONTICS
CASE HISTORY

Date:

Patient's Name: Occupation:

Age : Sex: Tel. No. :

Address :

Chief Complaint:

History of Present Complaint:

Period of edentulousness -

Etiology of teeth loss - Periodontal disease / caries/ both & others

Previous denture experience: Yes / No

Type of restoration : CD / PD / F P.D

Duration of Restoration :

Medical History:

Relevant medical history about heart diseases____________,

Diabetes________________, Tuberculosis_________, Arthritis__________,

Asthma_________, Epilepsy_________, Rheumatic fever, or any other disease_______________, Hypertention_____________

- Anemia, Jaundice and Cyanosis
- History of allergies/ hyper sensitivities
- Chewing habit – Betel nut, Tobacco chewing
- Personal habits – Diet, Smoking, Alcoholic

Clinical Examination :

General

__ General health of patient with build

__ Examination of lymph nodes

Extra oral Examination:

Facial Examination:

- Facial form : Ovoid / Tapering / square/Squarish ovoid
- Profile : Straight / Convex / Concave
- Facial symmetry : symmetrical / Asymmetrical

Hair Eye Complexion:

Lip Examination:

- Cracking, fissuring at commissures __ Yes / No
- Short / Long / Medium

TMJ Examination:

- Mouth Opening – Normal / Restricted
- Deviation of Mandible __ Present / absent
- Tenderness / Clicking / Crepitus __ Present / absent

Muscle Co-ordination -

- Movements Coordinated / Un-coordinated

Intra Oral Examination

Overall view for any abnormal pathoses in
Mucous membrane_____________,cheeks_____________, lips___________,
ridges___________, Floor of the mouth _______________, Hard, soft palate & tongue_________________.

Color of Mucosa: Pink / Pale Pink / Pigmented

Saliva:

Amount & flow : - Normal / Less /

Consistency : - Thin / Thick / Ropy

No. of teeth present :-

Plaque, calculus :-

Mobility grade :-

Pocket depth :-

Width of attached gingiva :-

Arch Size:

Maxillary - Large / Medium / Small

Mandibular - Large / Medium / Small

Arch Form:

Square / Ovoid / Tapering

Ridge Contour:

Upper U/V – Bulbous / Flat /Knife edge

Lower U/V – Bulbous / Flat / Knife edge

Ridge Relation:

Class I – Normal/Class II – Prognathic / Class III – Retrognathic

Amount of interridge space (Inter arch distance) – Less / Adequate

- __________ mm

Resorption:

Maxilla - Slight / Moderate /Severe

Mandible - Slight / Moderate /Severe

Mucosa covering the Ridge:

- Firmly attached Yes / No
- Presence of flabby tissue Present/Absent , Anterior / Posterior
- Hyperplastic changes Present/Absent

Soft Palate Contour (Throat Form)

- Class I / class II / Class III

Lateral Throat form (Disto- lingual sulcus)

- Class I / class II / Class III

Bony Undercuts:

- Anterior - Present/Absent
- Posterior - Present/Absent

Tori:

- Torus Palatinous - Present / Absent

- Torus Mandibularis - Present / Absent

Muscle & Frenum:

Attachments - Normal / High

Tongue:

- Size
- Movement and co-ordination

Floor of Mouth:

High / Low / Normal

Gag reflex:

Active / Hyper active

Provisional Diagnosis:

Radiography Examination:

Panoramic radiograph -

- Impacted Teeth - Present / Absent
- Root stumps - Present / Absent
- Foreign objects - Present / Absent
- Radiolucencies - Present / Absent
- Any other findings:-

Intra-oral periapical radiograph –

- Length of root with alveolar support –
- C/R ratio
- Any periapical/ periodontal finding –

Abutment teeth retained :-

Treatment Plan:

Treatment advised:

TABLE 7.1 - **BITE FORCE VALUES OF GROUP I (NATURAL DENTATE SUBJECTS) FOR RIGHT AND LEFT SIDES**

S.NO.	NAME, AGE AND SEX	BITE FORCE (N)	
		RIGHT SIDE	LEFT SIDE
1.	Mr. Pandian 49/M	309.6	305.7
2.	Mrs. Fathima Sheela 50/F	274.3	281.4
3.	Mrs.Gandimathi 52/F	278.6	273.2
4.	Mr. Sukumar 53/M	299.7	289.6

TABLE 7.2 - **BITE FORCE VALUES OF GROUP II (CONVENTIONAL COMPLETE DENTURES) FOR RIGHT AND LEFT SIDES**

S.NO.	NAME, AGE AND SEX	BITE FORCE (N)	
		RIGHT SIDE	LEFT SIDE
1.	Mrs. Sivagami 56/F	55.6	53.9
2.	Mr.Machendranath 54/M	67	64.8
3.	Mr.Sambandan 60/M	65.5	60.2
4.	Mrs.Palaniammal 48/F	59.4	57.6

TABLE 7.3 - **BITE FORCE VALUES OF GROUP III (SUBJECTS WITH BALL-CAP ATTACHMENT RETAINED TOOTH-SUPPORTED OVERDENTURES) FOR RIGHT AND LEFT SIDES**

S.NO.	**NAME, AGE AND SEX**	**BITE FORCE (N)**	
		RIGHT SIDE	LEFT SIDE
1.	Mrs. Shakuntala 50/F	186.5	187.1
2.	Mrs.Sarawathy 53/F	185.1	182.8
3.	Mr.Victor Paul 55/M	201.7	198.6
4.	Mrs. Rajamani 48/F	192.0	194.8

TABLE 7.4 - **BITE FORCE VALUES OF GROUP IV (SUBJECTS WITH BAR-CLIP ATTACHMENT RETAINED TOOTH-SUPPORTED OVERDENTURES) FOR RIGHT AND LEFT SIDES**

S.NO.	**NAME, AGE, SEX**	**BITE FORCE (N)**	
		RIGHT SIDE	LEFT SIDE
1.	Mr. Rajasekar 57/M	215.5	210.4
2.	Mrs. Parvathy 52/F	195.7	192
3.	Mrs. Fathima Beevi 60/F	190.3	194.9
4.	Mr. Munusamy 58/M	197.8	195.4

<u>TABLE 7.5</u> - MEASUREMENTS OF CHEWED TEST FOOD OBTAINED USING DIGITAL IMAGE ANALYSIS FOR <u>GROUP I</u> – SUBJECTS WITH NATURAL DENTITION

S.No.	Red Area (RA) in sq.mm	Green Area (GA) in sq.mm.	Maximum length (ML) in mm	Maximum breadth (MB) in mm	Total area (A) in sq.mm.	Projection of sample above 1mm (AH) in sq.mm
1.	13.45.	14.59	39	19.4	556.38	242.72.
	15.82	12.67				
2.	16.70	18.46	36	16.8	517.62	288.56
	17.57	19.52				
3.	17.88	15.59	35.7	17.6	521.84	306.84
	16.53	18.94				
4.	14.48	16.57	37.4	18	533.93	273.96
	15.77	17.42				

TABLE 7.6 **- VARIABLES DERIVED FROM THE MEASUREMENTS OF TABLE 7.5**

S.No.	MIX	TR	LB	FF
1.	95.16 94.88 **Mean** – 95.02	-129.22	2.010	28980403.92
2.	93.21 92.83 **Mean** – 93.02	-79.38	2.1428	29383652.64
3.	93.59 93.20 **Mean** – 93.39	-70.069	2.0284	30726497.16
4.	94.18 93.78 **Mean** – 93.98	-94.89	2.0777	30081536.73

TABLE 7.7 - DISCRIMINANT FUNCTION – MIXING ABILITY INDEX CALCULATED FROM TABLE 7.6

	MAI (mixing ability index)
1.	1.032
2.	0.965
3.	0.989
4.	0.997

TABLE 7.8 - MEASUREMENTS OF CHEWED TEST FOOD OBTAINED USING DIGITAL IMAGE ANALYSIS FOR GROUP II – CONVENTIONAL COMPLETE DENTURES

S.No.	Red Area (RA) in sq.mm.	Green Area (GA) in sq.mm	Maximum length (ML) in mm	Maximum breadth (MB) in mm	Total area (A) in sq.mm	Projection of sample above 1mm (AH) in sq.mm
1.	43.62	39.21.	19.4	12	202.59	189.35.
	38.03	41.72				
2.	32.43	35.58	23.5	14.8	247.94	197.32
	34.52	33.61				
3.	35.63	30.74	20.8	13.6	222.84	203.41
	32.94	36.39				
4.	34.90	32.68	21.5	13.2	228.41	198.79
	33.53	31.93				

TABLE 7.9 - DISCRIMINANT FUNCTION – MIXING ABILITY INDEX

	MAI (mixing ability index)
1.	0.280
2.	0.265
3.	0.268
4.	0.273

TABLE 7.10 - MEASUREMENTS OF CHEWED TEST FOOD OBTAINED USING DIGITAL IMAGE ANALYSIS FOR GROUP III – SUBJECTS WITH BALL AND CAP RETAINED TOOTH SUPPORTED OVERDENTURES

S.No.	Red Area (RA) in sq.mm.	Green Area (GA) in sq.mm.	Maximum length (ML) in mm	Maximum breadth (MB) in mm	Total area (A) in sq.mm	Projection of sample above 1mm (AH) in sq.mm.
1.	26.43	27.76	28.6	16	357.23.	64.82
	28.65	25.51				
2.	25.43	27.28	30	15.8	360.89	62.23
	21.06	29.45				
3.	21.76	20.98	32.8	18	390.4	50.73
	22.54	18.39				
4.	27.89	24.83	30.2	17.9	377.80	55.76
	28.43	25.08				

TABLE 7.11 - DISCRIMINANT FUNCTION – MIXING ABILITY INDEX

S.No.	MAI (mixing ability index)
1.	0.684
2.	0.692
3.	0.716
4.	0.709

TABLE 7.12 - MEASUREMENTS OF CHEWED TEST FOOD OBTAINED USING DIGITAL IMAGE ANALYSIS FOR GROUP IV – SUBJECTS WITH BAR AND CLIP RETAINED TOOTH SUPPORTED OVERDENTURES

S.No.	Red Area (RA) in sq.mm.	Green Area (GA) in sq.mm.	Maximum length (ML)in mm	Maximum breadth (MB) in mm	Total area (A) in sq. mm	Projection of sample above 1mm (AH) in sq. mm
1.	27.93	23.76	35	19	382.74 .	54.56
	21.65	25.51				
2.	31.43	28.33	33.9	17.2	366.89	61.39
	29.67	26.32				
3.	32.76	29.98	32.5	16	351.87	63.93
	30.02	31.69				
4.	24.89	20.83	36	19.6	387.65	52.76
	20.19	21.64				

TABLE 7.13 - DISCRIMINANT FUNCTION – MIXING ABILITY INDEX

S.No.	MAI (mixing ability index)
1.	0.724
2.	0.702
3.	0.698
4.	0.718

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